14-c

January 1960

75¢

SEMICONDUCTOR PRODUCTS

A Review of Parametric Diode Research

60 MC I.F. Amplifier Using Silicon Tetrodes

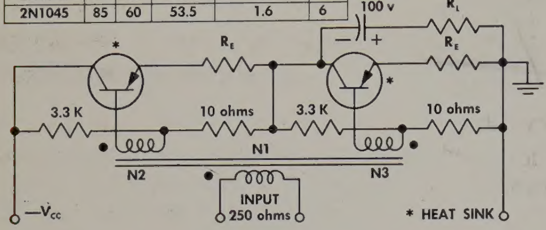
Silicon Carbide in High Temperature Rectifiers

Your best combination of I_{CBO}-R_{CS}-V-PLUS HIGH BETA ...TI germanium power transistors!

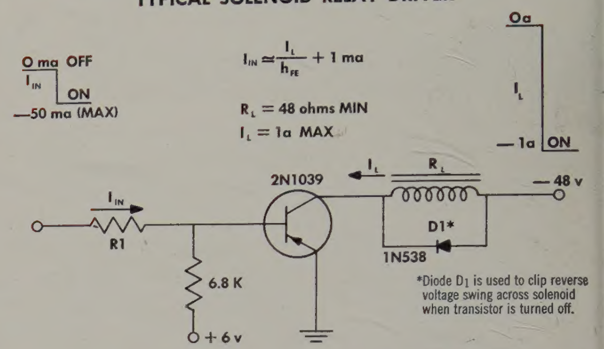
TYPICAL AUDIO AMPLIFIER 10 WATTS OUTPUT

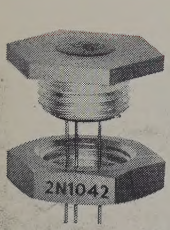
TRANSISTOR	V_{CC} volts	R_L ohms	Efficiency %	Distortion % at P_O=10w	R_E ohms
2N1042	35	10	58	2.7	1
2N1043	55	25	57	1.8	2.5
2N1044	70	40	56	1.6	4
2N1045	85	60	53.5	1.6	6

Transformer: N_1:N_2:N_3 = 1:1:1
To Minimize Cross-Over Distortion the Coils Should be Bifilar Wound.



TYPICAL SOLENOID RELAY DRIVER





ACTUAL SIZE

20-w power transistors:

switching circuits • relay drivers • audio and pulse amplifiers

TI 2N1042 series alloy-junction transistors **guarantee** 20 w dissipation at 25°C with voltage ratings of —40, —60, —80, and —100 v. You get guaranteed 20-to-60 beta spread at —3 amps and low 0.16 ohm saturation resistance at the —3 amp maximum collector rating.

ACTUAL SIZE

1.25-w power transistors:

medium speed switching circuits • relay drivers low-power audio and pulse amplifiers

TI 2N1038 series alloy-junction transistor **guarantee** 1.25 w dissipation in moving fre air at 25°C with voltage ratings of —40, —6 —80, and —100 v. **Guaranteed** 20-to-60 bet spread at —1 amp and low 0.2 ohm saturatio resistance assure reliable performance.

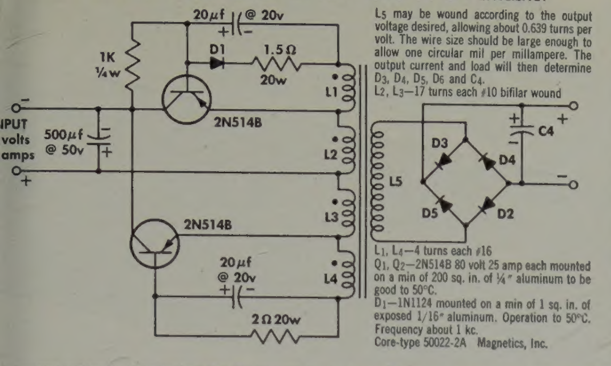
TI GERMANIUM POWER TRANSISTOR CHARACTERISTICS AT 25°C

Type	Dissipation at 25°C Watts	Max Collector Voltage Volts	Max Collector Current Amps	h_{FE} min	h_{FE} max	Collector Reverse Current I_{CO} max	Typical Saturation Resistance R_{CS} Ohms
2N456	50	—40	—5	10 @ —5a	50	—2ma @ —40v	0.048
2N457	50	—60	—5	10 @ —5a	50	—2ma @ —60v	0.048
2N458	50	—80	—5	10 @ —5a	50	—2ma @ —80v	0.048
2N511	80	—40	—10	10 @ —10a	30	—2ma @ —20v	0.025
2N511A	80	—60	—10	10 @ —10a	30	—2ma @ —30v	0.025
2N511B	80	—80	—10	10 @ —10a	30	—2ma @ —40v	0.025
2N512	80	—40	—15	10 @ —15a	30	—2ma @ —20v	0.025
2N512A	80	—60	—15	10 @ —15a	30	—2ma @ —30v	0.025
2N512B	80	—80	—15	10 @ —15a	30	—2ma @ —40v	0.025
2N513	80	—40	—20	10 @ —20a	30	—2ma @ —20v	0.025
2N513A	80	—60	—20	10 @ —20a	30	—2ma @ —30v	0.025
2N513B	80	—80	—20	10 @ —20a	30	—2ma @ —40v	0.025
2N514	80	—40	—25	10 @ —25a	30	—2ma @ —20v	0.025
2N514A	80	—60	—25	10 @ —25a	30	—2ma @ —30v	0.025
2N514B	80	—80	—25	10 @ —25a	30	—2ma @ —40v	0.025
2N1021	50	—100	—5	10 @ —5a	30	—2ma @ —100v	0.08
2N1022	50	—120	—5	10 @ —5a	30	—2ma @ —120v	0.08
2N1038	1.25	—40	—1	20 @ —1a	60	—125μa @ —20v	0.2
2N1039	1.25	—60	—1	20 @ —1a	60	—125μa @ —30v	0.2
2N1040	1.25	—80	—1	20 @ —1a	60	—125μa @ —40v	0.2
2N1041	1.25	—100	—1	20 @ —1a	60	—125μa @ —50v	0.2
2N1042	20	—40	—3	20 @ —3a	60	—125μa @ —20v	0.16
2N1043	20	—60	—3	20 @ —3a	60	—125μa @ —30v	0.16
2N1044	20	—80	—3	20 @ —3a	60	—125μa @ —40v	0.16
2N1045	20	—100	—3	20 @ —3a	60	—125μa @ —50v	0.16
2N1046	35	—80	—3	20 @ —3a	160	—1ma @ —40v	0.9

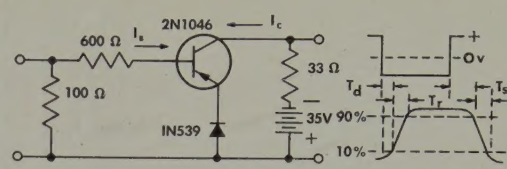
germanium and silicon transistors
silicon diodes and rectifiers
fan-TI-cap solid tantalum capacitors
precision carbon film resistors
sensistor silicon resistors

TEXAS

DC-TO-DC POWER CONVERTER 630-WATT OUTPUT AT 90% EFFICIENCY



TYPICAL SWITCHING CHARACTERISTICS



TYPICAL SWITCHING TIMES		
T_d	Delay Time	0.3 μsec
T_r	Rise Time	0.7 μsec
T_s	Storage Time	1.2 μsec
T_f	Fall Time	0.5 μsec

TEST CURRENTS	
I_{B1}	(Turn-on Current) = — 30mA
I_{B2}	(Turn-off Current) = + 30ma
I_C	(Collector Current) = — 1A

ACTUAL SIZE

10 to 25-amp switchers:
high current switching applications

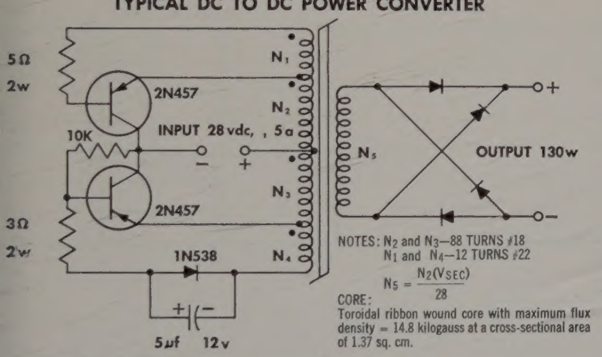
2N511 series alloy-junction transistors **guarantee** collector rrents of **—10, —15, —20, and —25 amps** in —40, —60 and 30 v ratings. All units provide low 0.025 ohm saturation resistce and typical switching times at 25°C of 12.5 μsecs (t_{on}) d 8.0 μsecs (t_{off}).

ACTUAL SIZE

high power/high frequency switchers:
computer core drivers • deflection circuits • light weight converter applications

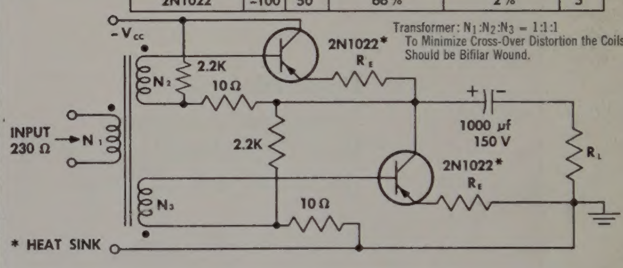
TI 2N1046 alloy diffused transistors combine high power, high frequency and high voltage performance in a single package. **Guaranteed** 35-w dissipation, collector breakdown voltage to —80 v, and low 0.75 ohm saturation resistance with **12 mc** typical alpha cutoff insure reliable operating characteristics.

TYPICAL DC TO DC POWER CONVERTER

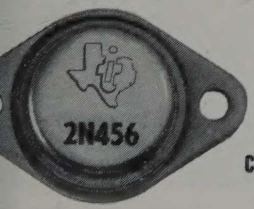


TYPICAL 20 WATT AMPLIFIER POWER GAIN = 23 db

TRANSISTOR	V_{cc} V	R_L Ω	EFFICIENCY	DISTORTION 20 WATTS	R_E Ω
2N1021	-80	30	66%	2%	3
2N1022	-100	50	66%	2%	5



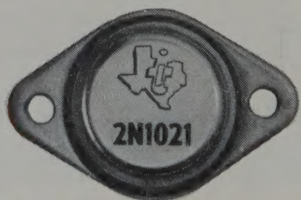
ACTUAL SIZE



high beta power amplifiers:
audio amplifiers • current switchers • power converters

2N456 series alloy-junction transistors with **guaranteed** w dissipation, **—40, —60, and —80** BV_{CBO} ratings and s than 0.048 ohm saturation resistance provide optimum rformance characteristics.

ACTUAL SIZE



high voltage power converters
audio • servo • power applications

TI 2N1021 and 2N1022 alloy-junction transistors **guarantee** maximum operating voltages of **—100 v and —120 v** respectively, low 0.08 ohm saturation resistance, and typical betas of 60 at —1 amp, 23 at —5 amps. You get **guaranteed** collector reserve current of —2 ma maximum at full rated voltage.

eck the specifications at left for the unit most suited to your particular requirements.

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Write on your company letterhead *to your nearest TI sales office* describing your application for specific details on TI products.

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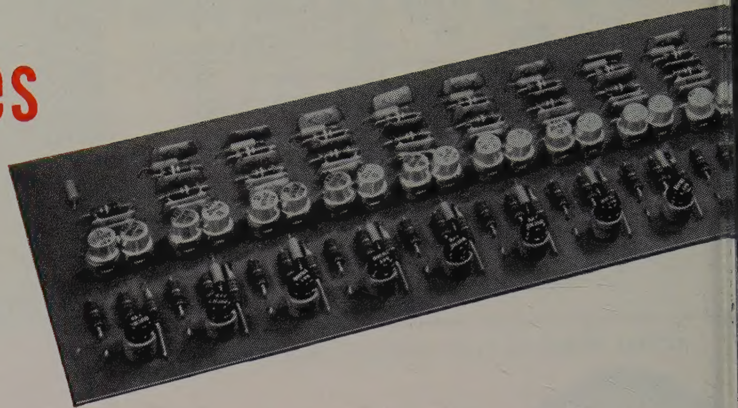
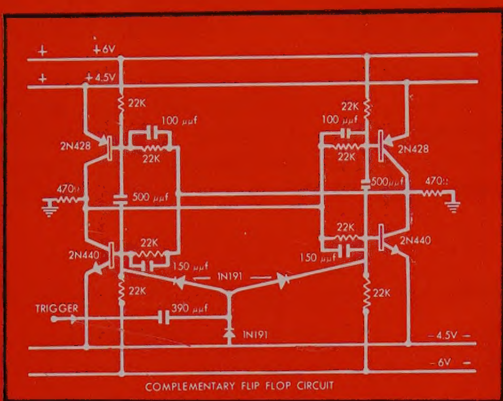
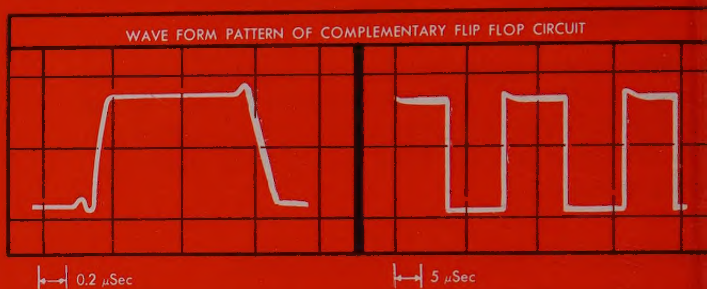
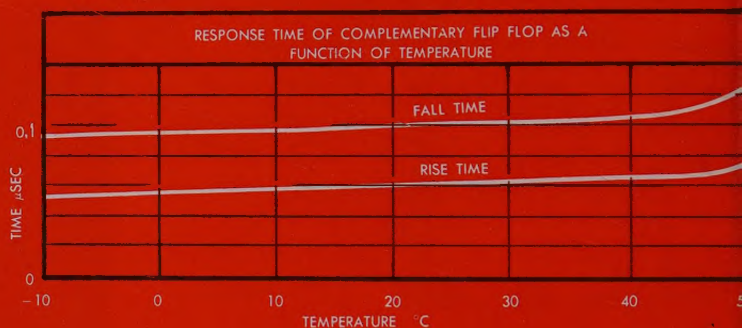
for switches



COMPLEMENTARY FLIP FLOP CIRCUIT



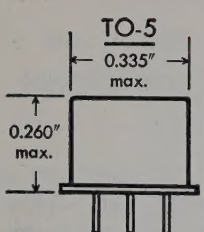




higher efficiency
symmetrical wave shape
lower output impedance
shorter rise and fall times

DESIGNED FOR COMPUTERS • MADE FOR COMPUTERS

Medium Current Switches



GERMANIUM PNP ALLOY — TO-5 CASE

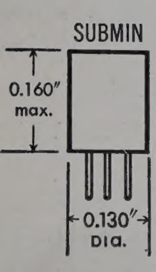
Type	V_{CE} Volts	$f\alpha_b$ Avg. Mc	H_{FE1} I_B = 1MA V_{CE} = 0.25V	H_{FE2} Min. I_B = 10MA V_{CE} = 0.25V	Rise* Time Max.
2N404	−24	12	—	—	—
2N425	−20	4	20–40	10	1.0
2N426	−18	6	30–60	10	0.55
2N427	−15	11	40–80	15	0.44
2N428	−12	17	60	20	0.33
2N1017	−10	22	80	20	0.27

*I_C = 50MA; I_{B1} = 5MA; R_L = 200Ω I_{B2} = 5MA

GERMANIUM NPN ALLOY — TO-5 CASE

Type	V_{CE} Volts	$f\alpha_b$ Avg. Mc	H_{FE} Min. I_C = 50MA V_{CE} = 1.0V	Rise Tim Avg µse
2N438	25	6	20	0.
2N439	20	11	30	0.
2N440	15	17	40	0.

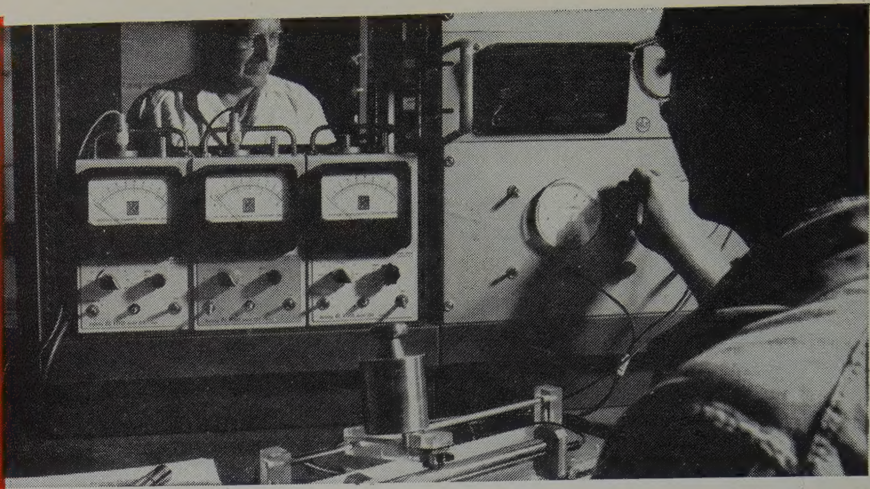
**I_{B1} = I_{B2} = 1MA; I_C = 10MA; R_L = 1KΩ



Contact the nearest Raytheon office for data on

SILICON as well as GERMANIUM Switching Transistors

MERCK HAS ALL FOUR FORMS OF



Measuring resistivity with digital voltmeter at Merck Control Laboratory, Danville, Pa.

Silicon

IN PRODUCTION QUANTITIES

BASE BORON CONTENT BELOW ONE ATOM OF BORON PER SIX BILLION SILICON ATOMS

***MERCK DOPED SINGLE CRYSTAL SILICON**—offers doped float zone refined single crystals of high quality at low costs. Yields of usable material are reported to be especially high when device diffusion techniques are used with these crystals. Float zone single crystals doped either "p" or "n" type with resistivities from *0.1 to 300 ohm cm.* any range plus or minus 25% with high lifetimes, available in diameters of 19 to 21 mm., and random lengths of 2 to 10 inches.

NOTE: *Doped single crystals float zone refined in other diameters, resistivities, or lifetimes not listed above can be furnished as specials.*

MERCK HIGH RESISTIVITY "P" TYPE SINGLE CRYSTAL SILICON—offers float zone refined single crystals of a quality unobtainable by other methods. Available with minimum resistivity of 1000 ohm cm. "p" type and a minimum lifetime of 200 microseconds, diameter 19 to 21 mm., random lengths 2 to 10 inches.

MERCK POLYCRYSTALLINE BILLETS—have not previously been melted in quartz, so that no contamination from this source is possible. Merck guarantees that single crystals drawn from these billets will yield resistivities over 50 ohm cm. for "n" type material and over 100 ohm cm. for "p" type material. Merck silicon billets give clean melts with no dross or oxides.

MERCK POLYCRYSTALLINE RODS—are ready for zone melting as received . . . are ideal for users with float zone melting equipment. Merck polycrystalline rods are available in lengths of 8½ to 10½ inches and in diameters of 18 to 20 mm. Smaller diameters can be furnished on special order. In float zone refining one can obtain from this material single crystals with a minimum resistivity of 1000 ohm cm. "p" type with minimum lifetime of 200 microseconds or the material can be doped by user to his specifications.

***NOTE:** *Extended resistivity range.*

For additional information on specific applications and processes, write Merck & Co., Inc., Electronic Chemicals Division, Department SP-16, Rahway, New Jersey.

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SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

January 1960 Vol. 3 No. 1

Front Cover

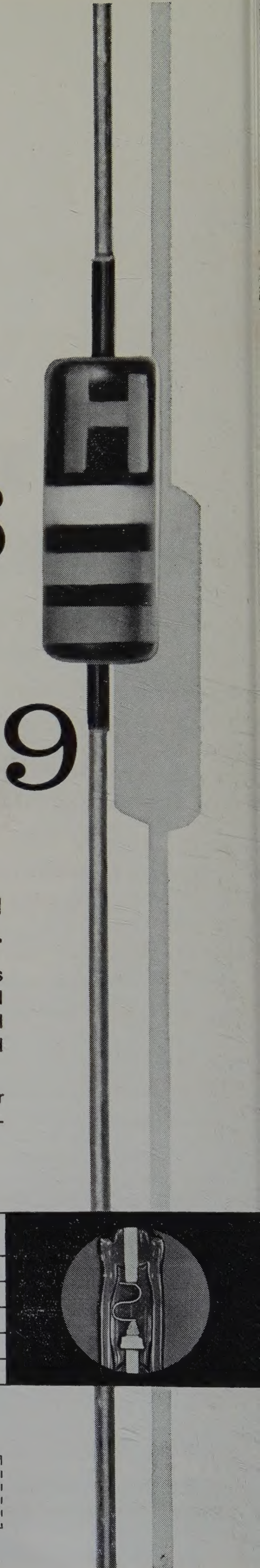
2nd Anniversary of SEMICONDUCTOR PRODUCTS magazine.

SEMICONDUCTOR PRODUCTS is published monthly by Cowan Publishing Corp. Executive and Editorial Offices: 300 West 43rd Street, New York 36, N. Y. Telephone: JUdson 2-4460. Subscription price: $6.00 for 12 issues in the United States, U. S. Possessions, APO, FPO, Canada and Mexico, $8.00 for 12 issues. All others: 12 issues $10.00. Single Copy 75¢. Accepted as controlled circulation publication at Bristol, Conn.

POSTMASTER: SEND FORM 3579 to SEMICONDUCTOR PRODUCTS, 300 West 43rd STREET, NEW YORK 36, N. Y.

4 day delivery: Fused Silicon Diodes

1N645 1N646 1N647 1N648 1N649



Hughes now offers you immediate delivery on five medium power fused silicon glass diodes—types 1N645, 1N646, 1N647, 1N648, and 1N649.

These Hughes diodes feature a Dumet-stud heat sink for small size and the popular Hughes glass package for proven reliability. Widely used in power supplies, magnetic amplifiers and similar circuits, these Hughes diodes are specially designed to meet the severe environmental requirements of such military equipment as missile telemetering links, airborne radar, and communication gear.

For immediate delivery of these Hughes diodes write, wire or phone the Hughes distributor or Semiconductor Division Sales Office nearest you...or write Hughes Semiconductor Division, Marketing Dept., Newport Beach, California.

Specifications

Type	Max. Working Voltage	Min. Forward Current @ specified voltage*	Max. Reverse Current at working voltage* (μA)	DC Current Io (μA)
1N645	225V	400 mA @ 1.0V	.2	400
1N646	300V	400 mA @ 1.0V	.2	400
1N647	400V	400 mA @ 1.0V	.2	400
1N648	500V	400 mA @ 1.0V	.2	400
1N649	600V	400 mA @ 1.0V	.2	400

* @ 25° C

SEMICONDUCTOR DIVISION

the West's leader in advanced ELECTRONICS **HUGHES PRODUCTS**

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or etching

nd washing

emiconductors . . .

3 & A® "ELECTRONIC-GRADE" HYDROGEN PEROXIDE

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pecial, new B&A "Electronic-Grade" H_2O_2, 30% nd 30% "stabilized"—with its stringent pH specifi- ations—reduces variations in rate of etch . . . cuts own rejects and improves quality control in the pro- uction of semiconductors.

o eliminate another variable in the use of hydrogen eroxide for semiconductor production, Baker & Adam- on® has now added label specifications for the pH of Electronic-Grade" H_2O_2, 30% and 30% "stabilized" see box). The pH for hydrogen peroxide, 30%, is 2.5-3.5 . . for 30% "stabilized," 3.0-3.5.

hese tight specifications provide still better control and uniformity of peroxide than in the past and elimi- nate variations from lot to lot. This is still another example of B&A's continuing leadership in supplying production chemicals of the highest purity and quality for the electronic industry. B&A "Electronic-Grade" Hydrogen Peroxide, 30%, is readily available in 1 lb. plastic bottles and 30-gallon polyethylene-lined drums. "Electronic-Grade" Hydrogen Peroxide, 30% "stabi- lized," comes in 1 lb. or 5 lb. glass bottles and in the 30-gallon drums.

Remember . . . for the purest hydrogen peroxide available . . . as well as for the highest quality in other electronic chemicals . . . specify B&A!

Check these stringent specifications

HYDROGEN PEROXIDE, 30% . . . CODE 2774
H_2O_2 M.W. 34.02

MEETS A. C. S. SPECIFICATIONS

Assay (H_2O_2)	29.0-32.0%
pH	2.5-3.5

MAXIMUM LIMITS OF IMPURITIES

Residue after Evaporation	0.002%
Free Acid (As H_2SO_4)	0.003%
Chloride (Cl)	0.0005%
Nitrate (NO_3)	0.0005%
Phosphate (PO_4)	0.00025%
Sulfate (SO_4)	0.0005%
Ammonium (NH_4)	0.0005%
Heavy Metals (as Pb)	0.0001%
Iron (Fe)	0.00005%

HYDROGEN PEROXIDE, 30% "STABILIZED" . . . CODE 2775
H_2O_2 M.W. 34.02

Assay (H_2O_2)	29.0-32.0%
pH	3.0-3.5

MAXIMUM LIMITS OF IMPURITIES

Residue after Evaporation	0.03%
Free Acid (as H_2SO_4)	0.005%
Chloride (Cl)	0.0005%
Phosphate (PO_4)	0.020%
Sulfate (SO_4)	0.001%
Heavy Metals (as Pb)	0.0001%
Iron (Fe)	0.00005%

HYDROGEN PEROXIDE, 3% SOLUTION . . . CODE 2773
H_2O_2 M.W. 34.02

Assay (H_2O_2)	3.0-3.5%

MAXIMUM LIMITS OF IMPURITIES

Residue after Evaporation	0.020%
Free Acid (as H_2SO_4)	0.010%
Chloride (Cl)	0.0005%
Nitrogen Compounds (as N)	0.005%
Phosphate (PO_4)	0.003%
Sulfate (SO_4)	0.005%
Arsenic (As)	0.00001%
Heavy Metals (as Pb)	0.0001%
Iron (Fe)	0.00005%
Preservative	0.035%

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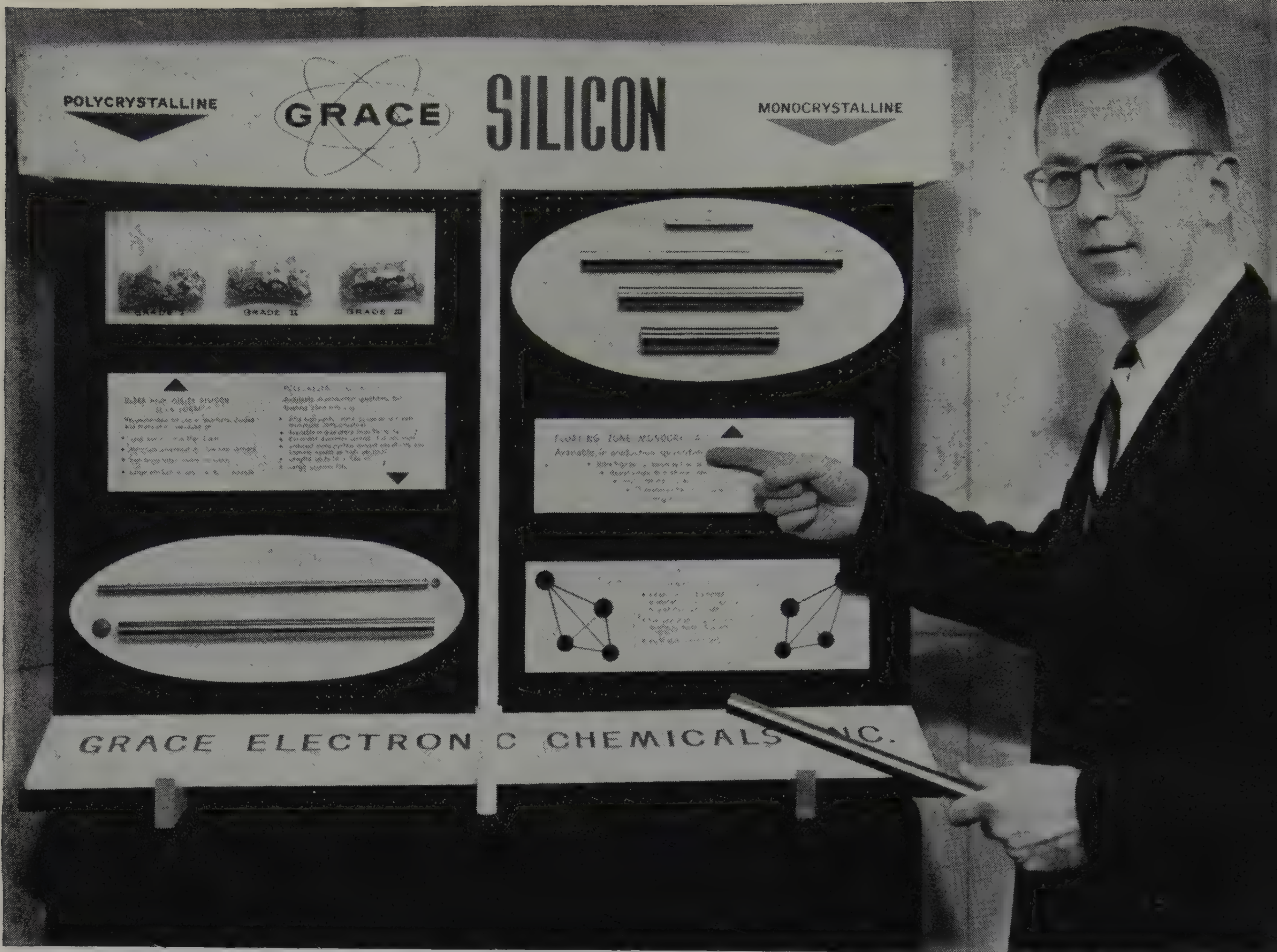
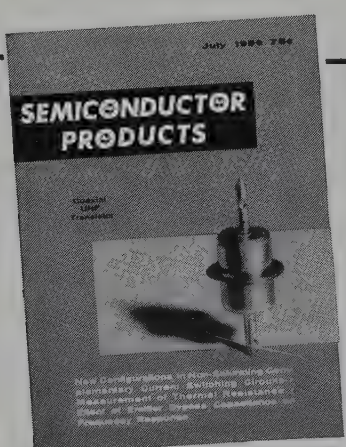


Grace Electronic Chemicals uses unique merchandising approach to introduce new products!

"Merchandising the Grace Electronics advertising campaign in SEMICONDUCTOR PRODUCTS by sending individual gift subscriptions to key customers and prospects has proved a valuable aid!" says Mr. Robert Herrmann, Vice President and Sales Manager of Grace Electronic Chemicals in Baltimore, Maryland.

Introducing Grace ultra high purity Silicon to an entire industry calls for a touch of ingenuity. Grace Electronics knew that SEMICONDUCTOR PRODUCTS reached the companies interested in their products, but to pinpoint those particularly interested in Silicon they sent each one of them a gift subscription to the magazine. Response to this unusual merchandising promotion not only brought thanks, but also produced inquiries and sales.



The semiconductor industry is a dynamic field that requires raw materials and equipment from more than 60 other industries. The chemical, ultrasonic, welding, metallurgical, paper, wire, abrasive and machinery industries are just a few of the areas that have found new markets in semiconductor production sales. Your product or service may have a place in this one-half billion dollar picture. Why not investigate the possibilities today?

SEMICONDUCTOR PRODUCTS

300 West 43rd Street, New York 36, New York

Editorial . . .

Semiconductor Photoelectric Cells

The use of photoelectric cells of semiconductor material antidates the development of the transistor; in fact certain effects, such as the photovoltaic effect of rectifying contacts, were discovered during the last century (see Adams and Day, "The Action of Light of Selenium," Proc. Royal Soc. 1877). However, the art has made great progress in recent years, partly because of the discovery of *p-n* junctions, and partly because of the availability of novel semiconductor materials. Although the primary effect on which such devices are based is the photoelectric effect, i.e. the ionization produced by photon impact, secondary phenomena, such as the photoconductive and the photovoltaic phenomenon are often utilized.

The photoconductive effect is based on the change of conductivity produced by the liberated carriers. The devices are formed with very thin films, bridging the gap between metal electrodes, so that the conductivity change is a large percentage of the total conductivity. The maximum frequency of response is limited by the minority carrier lifetime and is of the order of 5 *kc*.

When the carriers are generated within the vicinity of a *p-n* junction biased in reverse, all of the liberated carriers can be collected and the yield electron-photon approaches unity. Furthermore, if the *p-n* junction is part of a transistor, current multiplication in the latter may be used to increase the yield to about 25 times. The frequency response of these devices is also larger, because of the larger electric fields existing in the barrier region of a *p-n* junction; in practice, cutoff frequencies of the order of 200 *kc* are obtained.

When the *p-n* junction is left unbiased and with open circuit, an *emf* is generated, which produces a difference of potential of about 0.5 volts in a silicon unit. This may be utilized for direct reading of the light intensity or for power production in a load. For example the so-called solar cell is capable of a power conversion efficiency up to about 8%. The applications of the latter device in terrestrial and extra-terrestrial locations are well known.

Other important applications of the photoelectric cells are found in the field of radiation detectors. In this case the two important types of realizations are the image orthicon and the vidicon. The first device uses a photoemissive cathode the output of which is multiplied electronically and made to produce an electrostatic image on a screen, which is read by a scanning electron beam. The second device uses a photoconductive active element, whose surface voltage distribution varies with the light intensity, and which is read again by a scanning electron beam.

Finally it is known that a semiconductor which is transparent to infrared radiation may be made partially opaque to it if scanned with an electron beam. The latter is absorbed in direct relation to the intensity of the infrared image. Such a phenomenon may then be utilized to read out infrared images.

Correction

We wish to call attention to our December 1959 issue cover photograph and its explanation on page 5 under the heading "Front Cover," which reads "Printed micro-circuit process developed by James R. Nall and his coworkers of Fairchild Semiconductor Corp., etc., etc." This portion of the descriptive paragraph was an error on our part, and the following facts are submitted as a means of clarification to our readers and to give proper credit to those involved. These micro-circuits in the field of microminiaturiation came into being in 1957 with work carried on at the Diamond Ordnance Fuze Laboratories in Washington. Completed in late 1957, this item was a successful entry in, and received the top award at the first National Microminiaturization Award Dinner sponsored by Miniature Precision Bearings Corp. for the year 1958. A basic patent was awarded the Department of the Army under the names of Dr. Jay Lathrop and Mr. James R. Nall (then employees at DOFL.) This past fall Dr. Lathrop, now at Texas Instruments Inc., and Mr. Nall, together with three other DOFL employees received a total cash award of twenty-five thousand dollars for this development (each received five thousand dollars) representing the highest cash award possible under the Army system. The other members of the award winning team were Mrs. Edith Davies Olson, Mr. Norman Doctor and Mr. Thomas Prugh. Mr. Prugh is now with the National Security Agency. Mr. Nall joined Fairchild Semiconductor Corp. last summer and his return to Washington was requested to participate in the award ceremony held in the Pentagon only a month or two after his departure from government service. Fairchild Semiconductor Corp., in addition to manufacturing these micro-circuits, is engaged in extensive research in the micro-miniaturization field.

Staff Changes

We regretfully announce the resignation of Dr. John Dropkin from our staff of Advisory Editors. The pressure of other activities has necessitated this action on his part. At the same time, we are pleased to welcome Charles D. Simmons to our staff of Advisory Editors.

Samuel L. Marshall

BOOK REVIEWS . . .

TITLE: Modern Transistor Circuits

AUTHOR: John A. Carroll, Editor

PUBLISHER: McGraw-Hill 1959

Modern Transistor Circuits is another of the McGraw-Hill comprehensive collections of circuits, articles and nomographs originally published in Electronics magazine.

As in other books of this series, the material is categorically arranged in terms of circuit types and circuit applications. There are seventeen classifications.

The early chapters deal with the design of transistor amplifiers. There are collections of *h*-matrix parameters and conversion formulae in addition to several very useful nomographs for thermal stability. Several unusual designs utilizing melt-back tetrode transistors are discussed together with typical circuitry for more familiar units.

Other sections of the book deal with the design and development of various types of transistor oscillators, power supplies and associated equipment. Chapter V is a very interesting review of pulse circuitry. Several useful designs for multivibrators and high speed flip-flops are clearly developed and final circuits are shown. An interesting adjunct to this chapter may be found in Chapters XVI and XVII which deal with computer circuit design and computer auxiliary equipment.

The balance of the book covers a wide variety of topics. Scientific and medical instruments, industrial detection circuits, test instruments and industrial control circuits are but a few of the categories.

A book of the type of *Modern Transistor Circuits* fills a definite void between the research engineer and the "hardware" design engineer. The book presents the end results of many development projects, saving much time and effort for the circuit designer capable of adapting the material to his own needs.

TITLE: Transistors in Radio, Television and Electronics 2nd Edition

AUTHOR: Milton S. Kiver

PUBLISHER: McGraw-Hill 1959

Transistors in Radio, Television and Electronics is a complete revision of an earlier edition which indicates the remarkable growth of transistor electronics. To the uninitiated engineer this book is excellent first introduction. It is perhaps a better book for the advanced technician interested in obtaining a working knowledge of transistors.

Chapter I is a mathematics-free introduction to the modern electron theory. The presentation is exceptionally clear although not detailed. Chapters II and III elaborate upon atomic structure and develop the crystal lattice structure approach. Some very excellent illustrations do much to clarify the presentation. Point-contact and junction transistors are discussed and typical characteristics, curves, and design data are presented.

The balance of the book is devoted to

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TLE: Radio Engineering Hand

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UBLISHER: McGraw-Hill 1959

Radio Engineering Handboo
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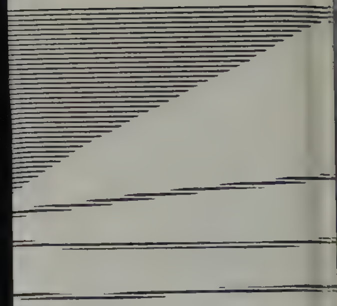

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A Review Of Parametric Diode Research

G. C. MESSENGER*

A number of approaches have been considered to obtain variable-capacitance diodes having a high cut-off frequency. These include finding the best material, using the optimum contact geometry, obtaining the best impurity doping gradient and choosing a good package. Several III-V intermetallic compounds have been evaluated in addition to germanium and silicon. Gallium arsenide seems to be the best material presently available for parametric diodes. It maintains high mobility and high breakdown voltage even at very high impurity doping levels. At low microwave frequencies, area contacts can be used, but at higher microwave frequencies, point contact diodes will be required. Over the entire frequency spectrum, the microetch structure produces advantages†. The homogenous base junctions have a larger capacitance variation than do the graded base types, so that as far as an impurity gradient is concerned, it does not seem necessary, especially if a thin base is used. There are three requirements for the microwave package. It must have a low shunt capacitance and a low series inductance and it must be mechanically designed to fit waveguide or coaxial structures.

THE USE OF the variable-capacitance characteristic of microwave diodes to get frequency conversion and amplification has received renewed interest. Experimentally, the effect is derived from the fact that a good *p-n* junction in the reverse bias condition is a high Q capacitance over a very wide frequency range. Recent literature has provided a good theoretical basis for utilizing these devices in electronic circuits.[1,2,3]

This article will confine itself to a discussion of the design problem posed by the variable-capacitance diode for applications at microwave frequencies. It has been shown[3] that the cut-off frequency is a figure of merit for these diodes. This is the same figure of merit which had previously been used for microwave mixer diodes[4] and provides a good analytical starting point. In addition, a variable-capacitance diode is required to have a high back resistance and, for most applications, a breakdown voltage of about 10 volts minimum.

Variable Capacitance Design

A. Material

The first problem which should be solved is which semiconductor should be used. This is best decided by using the figure of merit and subsequently checking to be sure that the desiderata of high back resistance and reasonable breakdown voltage are met. A large number of materials have been considered,[5] but only four are of sufficient interest to be concerned with here. They are germanium, silicon, gallium arsenide, and indium antimonide. The figure of merit used here is given by the cut-off frequency, f_c:

$$f_c = \frac{1}{2\pi\, R_s C_o} \qquad (1)$$

where R_s denotes series resistance of the diode, and C_o the capacitance of the diode excluding the diode package, at zero volts across the diode. This figure of merit for a homogeneous base material in terms of material parameters becomes:

$$f_c \propto N^{1/2} b/\epsilon^{1/2} \qquad (2)$$

where ε is the relative dielectric constant, N is the carrier concentration, and b is the carrier mobility. Assuming 100-percent ionization of impurities, N is also the impurity concentration. Jenny[6] has shown that the figure of merit for gallium arsenide should have been, perhaps 1½ times higher than for germanium. Recent measurements indicate that it may actually be more than twice as high as in germanium.

Figure 1 shows a comparison between measured values for b and $N^{1/2}\, b/\varepsilon^{1/2}$ for silicon, germanium, and gallium arsenide at a value of $N = 10^{18}$ cm^{-3}.

Thus gallium arsenide now looks better than earlier theoretical work seems to have indicated.

Indium antimonide, despite its high mobility, will only be feasible if cooled, and then only if its leakage resistance can be made very high.

The other necessary properties for variable-capacitance diodes—high back resistance and high break-

*Hughes Aircraft Company, Hughes Semiconductors, Newport Beach, California.

†G. C. Messenger, "New Concepts in Microwave Mixer Diodes," *Proc. IRE, 46, No. 6*, pp. 1116-1121 (June 1958).

down voltage—are also found in gallium arsenide. Thus, the following experimental evidence, *Fig. 2*, was obtained by comparing point contact diodes made on material with a carrier density of $\approx 10^{18}$ cm^{-3}.

B. Geometry

The next major design consideration is the geometry of the contact structure. To begin with, at the present state of the art of area-contact technology, contact diameters of a minimum of about 1 mil are possible; whereas, the corresponding frontier for point contact technology is found to be contact diameters of 0.2 mil. Thus, reduction in junction capacity of more than an order of magnitude will be possible by changing from area-contact to point contact technology. Therefore, to go substantially above some cut-off frequency, perhaps about 200 kmc, it will be necessary to employ point contact techniques.

At the present state of the art, point contact devices have much lower values of back resistance than area contact devices. This is a serious limitation for variable-capacitance devices. The only exception to this limitation, so far, has been some very promising results with point contact gallium-arsenide diodes.

The thickness of a semiconductor blank is a serious limitation on device performance, because the series resistance R_s is a monotonically increasing function of blank thickness. But on the other hand, "microetch" technology[4] makes it possible to realize membrane thickness of as little as 0.02 mil at the present state of the art.

It is therefore possible, with microetch technology, to provide sufficient semiconductor material for the depletion region only and eliminate completely the base region of the diode. This is very desirable since the base region can only have a harmful effect proportional to its size or to the series resistance which it introduces. The ideal parametric diode is thus seen to have a rectifying contact to one side of the depletion region and an ohmic contact to the other side of the depletion region with the base completely eliminated.

This microtech technology can be used *even in conjunction with point contacts* to further reduce the values of R_s. *Fig. 3* shows the microetch structure used with germanium point contact diodes.

Again, as the blank thickness is reduced to very small dimensions, the back resistance begins to drop. One effect causing the drop is the high generation of hole-electron pairs at the back surface.[7] However, a complete analysis has not been undertaken.

C. Impurity Distribution

Here a complete treatment has not been attempted because the design problems have not been solved completely. Rather, several ideas are presented to indicate the present status. In a homogeneous structure, the effective electrical base width determines the spreading resistance, and this can be controlled by adjusting the reverse bias on the diode.

If operating voltage range becomes a problem, the use of a gradient may permit a useful decoupling of the diode junction and base, just as grading a transistor base decouples the emitter and collector.

The impurity distribution in the depletion region need not be restricted to constant, linear, error function exponential, but may take more esoteric forms such as the high density center and low density edge distribution recently proposed for transistor base regions.[8]

As far as the C versus V characteristic is concerned, the square root law, which is characteristic of the junction on homogeneous material, is probably more desirable than the smaller variation with voltage which one gets from the graded junction.

Further, for some applications, such as harmonic generation, it is probably beneficial to have a high breakdown voltage and a larger variation of capacitance with voltage, whereas for other applications, such as amplification a much smaller breakdown voltage and capacitance variation may be beneficial.

Until the relative importance of the C versus V characteristic, the magnitude of the required voltage drive, and the desirable operation impedance levels become more standardized, it will be well to look at every available design possibility. It certainly should be possible to make good, reproducible, variable-capacitance diodes in homogeneous-base material and thus would be in keeping with the old maxim, "Learn to walk before you try to learn to run."

Material	Carrier Mobility b (cm^2/volt-sec)	Figure of Merit $N^{1/2}b/\epsilon^{1/2}$ (cm$^{1/2}$volt-sec)
P-Silicon	170	1.5×10^{10}
N-Silicon	1000	8.5×10^{10}
P-Germanium	1500	1.1×10^{11}
N-Germanium	2000	1.5×10^{11}
N-Gallium Arsenide	3500	3.5×10^{11}

Fig. 1. Figure of Merit for Several Ingots of Microwave Diode Materials

Material	Breakdown Voltage V_B (Volts)	Back Resistance R_B
N-Germanium	1-2	50-100 kilohms
P-Silicon	2-4	50-200 kilohms
N-Gallium Arsenide	6-10	0.25-2 megohms

Fig. 2. Comparison of Back Characteristics for Silicon, Germanium and Gallium Arsenide Point Contact Diodes

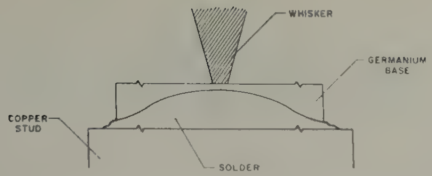


Fig. 3—Microetch point-contact diode structure.

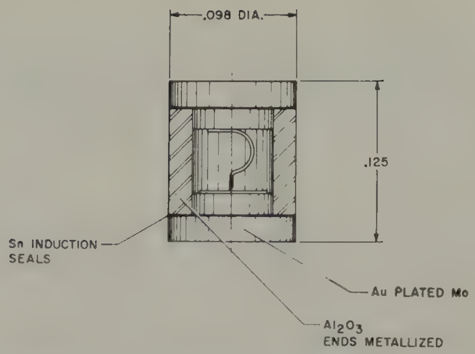


Fig. 4—Proposed microwave diode package which could be used in stripline or in waveguide circuits.

D. Package

The last problem concerns the package. It must have a low value of capacitance and a low value of inductance and must be a mechanically rigid structure for use in waveguide or coaxial circuits. The use of special whisker contact techniques to minimize lead inductances will be required for broadband circuits.

There are several good packages available. A proposed package is shown in *Fig. 4*, having a very small capacitance and inductance, and having a symmetrical feature for easy reversibility in microwave circuits. A slimmed-down version could be made having even lower capacitance and inductance. This package could be used in either waveguide or stripline circuits.

Conclusion

The best material on the horizon for use as a variable-capacitance diode is gallium arsenide. Its superiority over germanium and silicon comes from its higher values of carrier mobility, diode-breakdown voltage, and diode back resistance—even at high doping levels.

The best geometry for diodes with a cut-off frequency below about 200 *kmc* will probably be an area junction on a microetch base. The best geometry above about 200 kmc will probably be a point contact on a microetch base. This structure reduces to the depletion region itself and reduces the design problem to the design of the depletion region.

The question of whether to use graded base material or homogeneous base materials will not be decided until a more detailed knowledge of the required diode characteristics is obtained. Homogeneous base diodes are quite capable of operating as good parametric diodes.

Special microwave packages are required to minimize capacitance and inductance and to provide strong mechanical housings for accurate positioning in microwave and coaxial circuitry.

References

[1] J. M. Manley and H. E. Rowe, "Some General Properties of Non-Linear Elements, Part I: General Energy Relationships," *Proc. IRE*, 44, No. 7, pp. 904-913 (July 1956).

[2] H. E. Rowe, "Some General Properties of Non-Linear Elements, Part II: Small Signal Theory," *Proc. IRE*, 46, No. 5, pp. 850-860 (May 1958).

[3] A. Uhlir, "Potential of Semiconductor Diodes in High Frequency Communication," *Proc. IRE*, 46, No. 6, pp. 1099-1115 (June 1958)

[4] G. C. Messenger and C. T. McCoy, "Theory and Operation of Crystal Diodes as Mixers," *Proc. IRE*, 45, pp. 1269-1283 (Sept. 1957).

[5] A Coblenz, "Semiconductor Compounds Open New Horizons, *Electronics*, 30 No. 11, pp. 144-149, (Nov. 1, 1957).

[6] D. A. Jenny, "A Gallium Arsenide Microwave Diode," *Proc. IRE*, 46 No. 4, pp. 717-722, (April 1958).

[7] R. H. Rediker and D. E. Sawyer, "Very Narrow Base Diodes," *Proc. IRE*, 45, pp. 944-953, (July 1957).

[8] "Stored Charge Method of Transistor Base Transit Analysis," L. J. Vernerin, *Proc. IRE*, pp. 523-527 (April 1959).

60-MC I-F Amplifier Using Silicon Tetrodes

GLENN E. PENISTEN*   DONALD B. HALL*

This article describes the design of a high-gain, wide-band 60 *mc i-f* amplifier suitable for use in radar and missile systems. The circuit possesses the advantages of small size and weight gained by transistorization. The transistors used, 3N35 silicon tetrodes, permit a design for high-temperature operation. Interchangeability of transistors is good and the design is representative of what may be accomplished with today's design techniques applied to high-frequency transistors. The design makes use of the capabilities of the silicon tetrode to obtain a compact, high-performance amplifier of wide potential usage.

COMPACT, HIGH-PERFORMANCE, intermediate-frequency amplifiers are widely used in radar and missile applications. The advantages in size and weight reduction to be gained by transistorization of these circuits are many. However, until recently, the attractiveness of this approach has been limited by low gain, poor interchangeability, and lack of environmental ruggedness.

Recent developments in silicon transistors have provided devices which overcome these objections and thus make practical the design of high-gain, wide-band *i-f* amplifiers. This article describes one such design which is representative of the capabilities of these devices.

Design Specifications

A set of design specifications was chosen to represent what might be used in a reconnaissance-type radar. Other applications could use the same design technique applied here. The detailed specifications are outlined in Table I.

TABLE I

Minimum Gain	100 *db*
Maximum Gain Variation	±5 *db* from −55°C to +85°C
Center Frequency	60 *mc*
Bandwidth	20 *mc* at 3 *db* down
No neutralization. Stability with changes in environment. Designed for future production.	

Silicon Tetrode Transistor

The design made use of a 3N35 silicon tetrode transistor. This device has been designed as a high-frequency amplifier, having a typical gain of 20 *db* at 70 *mc*. This high gain makes possible a 60-*mc i-f* amplifier of high performance using silicon transistors with their excellent high-temperature characteristics.

The high-frequency performance of the 3N35 is obtained by several means. The first is the use of a graded base-layer impurity distribution to increase the high-frequency performance of the basic grown structure. This is accomplished through the grown-diffused process.[1] Use of the tetrode structure[2] further enhances the high-frequency characteristics of the device, giving performance heretofore unobtainable in a production-type silicon transistor.

The design philosophy, physical construction, gain characterization, and electrical testing of the 3N35 have been covered at length by Earhart and Brower[3] to which the reader is referred for more detailed information. Other papers have discussed the electrical characteristics and some applications of the silicon tetrode.[4] [5]

Interstage Networks

After selection of a device suitable for the application at hand, an interstage network must be designed to provide the necessary bandwidth. Inevitably, compromises must be made between stability, bandwidth, and coupling loss. An additional factor to be considered is the bilateral nature of the transistor when used as an amplifier. The effects of this characteristic are more pronounced at high frequencies and are important in the choice of circuitry. This bilateral nature of the transistor may not necessarily be a cause of possible instability. For instance, four-terminal measurements show the 3N35 to be unconditionally stable above about 50 *mc* in the common-emitter connection. However, the bilateral characteristics may complicate tuning of the transformers because each stage interacts with the preceding and following stages.

One method of overcoming these difficulties is the use of neutralization. Neutralization or unilateralization makes each stage essentially independent of the

*Texas Instruments Incorporated, Dallas, Texas

others, but requires more complicated circuitry. To effectively obtain neutralization over a wide bandwidth, such as used in this design, requires a rather complicated network and even then involves a considerable amount of trial and error to ensure good performance.

Another approach to the problem is mismatch between stages. Since, as was mentioned previously, the 3N35 is stable at the frequencies used in this amplifier, stability is not the major consideration. Providing appropriate mismatch in the interstage coupling networks, reduces to a minimum the variations due to parameter differences between production units. Previous designs at 30 *mc* using similar techniques have included a 5:1 mismatch. This mismatch ratio sacrifices about 2.55 *db* in gain but experience has shown it to be sufficient for minimizing unit-to-unit variations.

Several designs were investigated in efforts to obtain a coupling network that was easy to construct and which gave the desired performance. A design using staggered doubles was attempted first. The design of such circuits is covered by Valley and Wallman.[6] Measurements had previously been made on a number of units. The quantities measured were the equivalent parallel input resistance (R_{iep}) and capacitance (C_{iep}), and the equivalent parallel output resistance (R_{oep}) and capacitance (C_{oep}). These measurements may be easily made on a Boonton RX meter using suitable jigs. Each measurement, either input or output is made with the other pair of terminals short circuited for signal frequencies. These measurements were used in the initial calculations.

(R_{oep})	Parallel Output Resistance	6.26 K ohm
(C_{oep})	Parallel Output Capacitance	1.7 μμf
(R_{iep})	Parallel Input Resistance	119.2 ohm
(C_{iep})	Parallel Input Capacitance	29.6 μμf

It should be emphasized that the results obtained from these measurements do not give the exact values of impedances which will appear in the circuit, but they do allow simple measurements which give good results in practice.

The values of these parameters which were measured are tabulated in Table II below:

TABLE II

	Minimum	Typical	Maximum
R_{oep}	3.5 K	5.0 K	8.0 K
C_{oep}	1.5	2.0	3.0
R_{iep}	100	200	400
C_{iep}	12	30	50

When the calculated networks were constructed it was found that the secondary of the interstage transformer resulted with the input capacity of the following stage within the pass-band of the amplifier. This gave a double-tuned effect, which was undesirable. In narrow band designs, this problem would not be present. No combination of transformer constants was found which would eliminate this difficulty. Because of this difficulty, it was decided to go to double-tuned interstages.

The coupling method chosen was transitionally-coupled, double-tuned interstages. The design of these networks is treated extensively in a report by Lawson and Stone.[7] Preliminary calculations revealed that such a design would provide approximately the 5:1 mismatch previously mentioned. The calculations for obtaining the transformer constants are outlined in the Appendix. The symbols used are those in the Lawson and Stone report. The values of transformer constants obtained are shown in Table III.

TABLE III

Primary Inductance	1.365 μh
Secondary Inductance	0.2475 μh
Coefficient of Coupling	0.43

Description of Single-Stage

Figure 1 shows a single stage of the eight-stage amplifier. All stages are identical except for the input and output stages whose transformers may be designed for the appropriate driving and load resistances, respectively.

The proper biasing of the stage is important to ensure optimum gain and interchangeability of units. Measurements made on large quantities of 3N35 units show that this device has optimum gain characteristics at an operating point of $V_{CE} = 20$ volts, $I_E = -1.3$ *ma*, and $I_{B2} = -0.1$ *ma*. To ensure adequate bias circuit performance from unit to unit under conditions of large ambient temperature variations, a two-battery circuit was employed. The negative supply was made 20 volts thereby providing a symmetrical arrangement. Each transistor is biased common base even though the *r-f* circuitry is common emitter. The large resistors in the emitter and base-two leads assure that the currents in these elements will remain constant. These resistors are bypassed for signal fre-

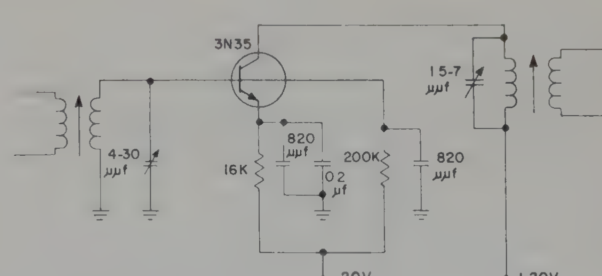


Fig. 1—One stage of the amplifier.

quencies by appropriate capacitors. An additional 0.2 μf capacitor helps ensure that the bias point will remain constant with a pulsed input signal. Decoupling is accomplished by the chokes and bypass capacitors shown in the complete amplifier schematic.

The *r-f* circuitry is straightforward. Trimmer capacitors tune both sides of the transformer; a 4-30 $\mu\mu f$ unit at the input to the transistor and a 1.5 to 7 $\mu\mu f$ in the collector circuit. The actual alignment of the amplifier will be described later.

Eight-Stage Amplifier

Figure 2 is a schematic of the entire amplifier. As previously mentioned, the input and output transformers depend on source impedance and load impedance, respectively. Table IV indicates the results obtained.

TABLE IV

Gain	105 *db*
Bandwidth	20 *mc*
Center Frequency	60 *mc*
Gain Variation to 85°C	−8 *db* (See following discussion on temperature performance)
No neutralization. Absence of regeneration. Design suitable for production.	

The final amplifier, when tested, exhibited a lack of any type of regeneration. The test results closely followed the performance expected from preliminary calculations. This lack of regeneration is due partly to the low impedance levels present in the circuit but primarily to impedance mismatch between stages. The ordinary considerations in the layout and packaging of high-frequency circuits apply to this design. The final form of the amplifier used a cover plate, but no evidence of instability could be detected without it.

The high temperature performance of the amplifier is shown in Table V. It should be pointed out that, in this design, the transistor is **not** the temperature-limiting item. By proper techniques, the change in gain at temperature extremes may be compensated for. One such technique is the use of a stage whose gain is purposely made a function of temperature to compensate for the gain change of the remaining stages.

TABLE V

Temperature (°C)	Gain (*db*)
25	105
56	104
66	102
71	101
75	100.5
77	100.0
80	99.5
83	97
85	97

Previous experience with other amplifier designs has shown that the gain tends to increase as the temperature is lowered. The corrective techniques mentioned above also would be of value at the lower temperatures.

The *agc* problems associated with this amplifier were not investigated extensively. Previous experience has shown that applying *agc* to the emitter and base-two provides the best characteristics with respect to center-frequency and bandwidth changes. With the *agc* arrangement shown in *Fig. 3* applied to the first three stages, about 60 *db* of control was obtained with negligible change in bandwidth.

Alignment

The problems of alignment are particularly important in an amplifier designed for possible production. To facilitate this alignment, the demodulator probe shown in *Fig. 4* was constructed. It consists of a resistor and a capacitor that simulate the input to the stage following the one to be tuned, plus a diode for demodulating the signal. The demodulated signal may be viewed on a high-gain, low-frequency oscilloscope. The probe has low strap capacitances and a flat frequency response so that the circuit under alignment

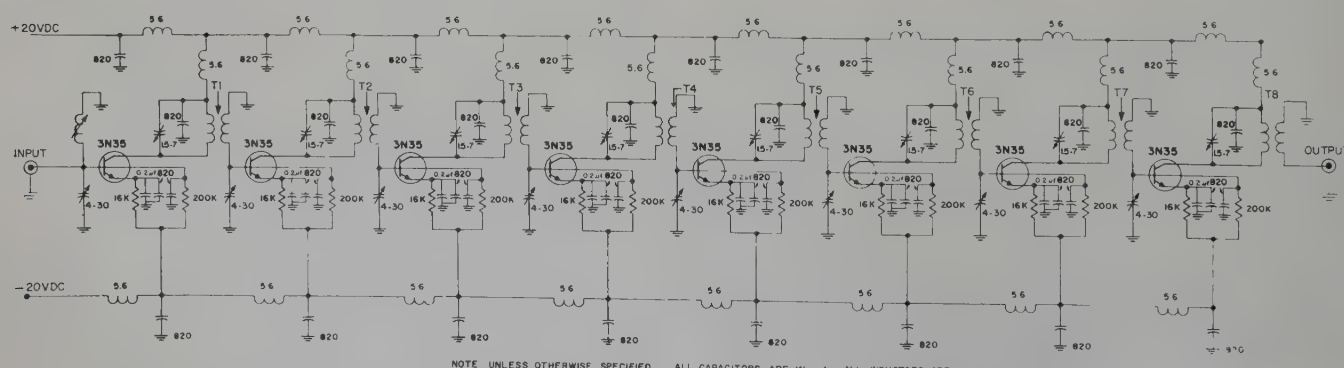


Fig. 2—Schematic of the 60 megacycle i.f. amplifier.

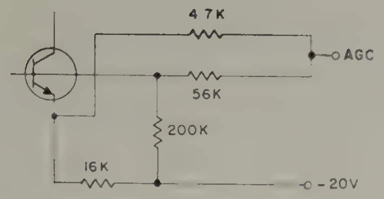


Fig. 3—Automatic gain control circuit.

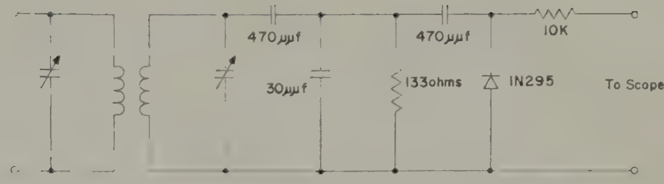


Fig. 4—Demodulator probe.

will not be detuned by the probe. All measurements were made on the low-impedance side of the transformers.

The testing was done using a sweep generator. This method permits the effect of minor adjustments to be evaluated rapidly and is recommended for any wide-band amplifier work. The effects of regeneration show up on this test as spikes and unexplained lobes in the passband.

The demodulator probe may be used in a step-by-step alignment. The first stage may be tuned with the demodulator probe substituted for the input circuit of the second stage. As each stage is added, the probe is moved and only a slight retouching of tuning will be necessary. Using this method of alignment, it becomes simple to tune-up the entire eight-stage amplifier in a short time.

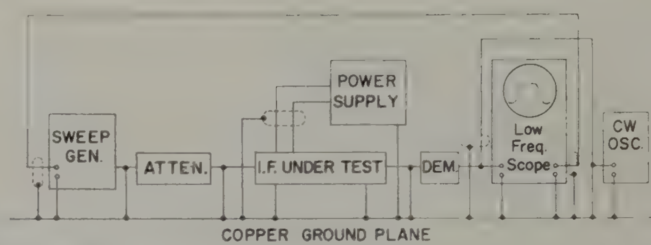
Test Set-Up

The test set-up used in the design of the amplifier is shown in *Fig. 5*. The importance of maintaining proper test conditions cannot be overemphasized. All equipment is grounded to a large copper sheet that acts as a common ground-plane. It is important that all equipment connected to the input side be physically located on that side. The same is true for the output side. By doing this, common ground paths which constitute one of the chief causes of measurement errors are eliminated.

Summary

The circuitry described in this article illustrates how a transistorized *i-f* amplifier of good performance can be designed. The availability of a silicon transistor having excellent high-frequency characteristics makes the transistorization of radar and missile *i-f* amplifiers feasible. Other methods of design may be used as the particular requirements dictate. Depending upon the bandwidth desired, gains of 10 to 20 *db* per stage can be expected. In general, higher gain may be expected at lower frequencies. In all cases, the success of the final circuit will be assured by careful attention to obtain the optimum utilization of the device capabilities.

The authors wish to acknowledge the measurement and experimental work of Tom Morris and Bob Harmon of the Apparatus Division, Texas Instruments Incorporated.



NOTE:
All Leads Should Be As Short As Possible
All Grounding Should Be Done With Copper Straps
All Signal Leads Should Be Co-Axial

Fig. 5—Block diagram of the test set-up.

Appendix

Description of the Interstage Transformer

The following calculations of the necessary constants are for interstage transformers utilizing double tuning and transitional coupling:

$$\lambda_1 = \frac{1}{\omega_o^2 C_1}\left[1 + \frac{\alpha_1^2}{8} + \frac{3\alpha_2^2}{8}\right]$$

$$\lambda_2 = \frac{1}{\omega_o^2 C_2}\left[1 + \frac{\alpha_2^2}{8} + \frac{3\alpha_1^2}{8}\right]$$

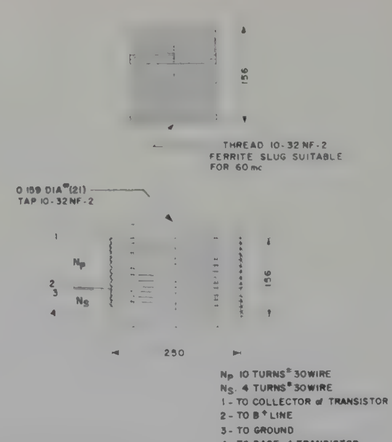


Fig. 6—Specifications of the interstage transformer.

$$\lambda_3 = \frac{1}{\omega_o{}^4 C_1 C_2}$$

$$M = \sqrt{\lambda_1 \lambda_2 - \lambda_3}$$

$$k = \frac{M}{\sqrt{\lambda_1 \lambda_2}} = \sqrt{1 - \frac{\lambda_3}{\lambda_1 \lambda_2}}$$

$$\alpha_1 = \frac{1}{\omega_o R_1 C_1}$$

$$\alpha_2 = \frac{1}{\omega_o R_2 C_2}$$

where

$\omega_o = 2\pi f_o$
f_o = design center frequency
λ_1 = primary inductance
λ_2 = secondary inductance
M = mutual inductance
k = coefficient of coupling
α_1 = primary dissipation factor
α_2 = secondary dissipation factor
R_1 = common emitter parallel output resistance
C_1 = total parallel primary circuit capacitance
R_2 = common emitter parallel input resistance
C_2 = total parallel secondary circuit capacitance

Calculations

The gain per stage was estimated at 12.5 *db*, with each stage designed for a 32-*mc* bandwidth.

Thus,

$$b = \frac{\Delta f}{f_o} = \frac{32}{60} = 0.533$$

where b = fractional bandwidth

However,

$$b = \frac{1}{\sqrt{2}}\left(\alpha_1 + \alpha_2\right),$$

so that the relationship $\alpha_1 + \alpha_2 = \sqrt{2}\,(0.533) = 0.754$ is obtained.

It was decided to design the transformer using a typical value of 5000 ohms for R_1 and $6\mu\mu f$ for C_1.

$$\alpha_1 = \frac{1}{\omega_o R_1 C_1} = \frac{1}{(2\pi)\,(60 \times 10^{-6})\,(5000)\,(6 \times 10^{-12})} = 0.0885$$

Thus $\quad \alpha_2 = 0.754 - 0.0885 = 0.6655$

Values of R_2 = 133 ohms and $C_2 = 30\ \mu\mu f$ were chosen. $\quad \alpha_2 = \frac{1}{\omega_o R_2 C_2}$

The transformer constants then were calculated as follows:

$$\lambda_1 = \frac{1}{(377)^2(10^{12})\,(6 \times 10^{-12})}\left[1 + \frac{(0.0885)^2}{8} + \frac{3(0.6655)^2}{8}\right] = 1.365 \times 10^{-6}\ hy$$

$$\lambda_2 = \frac{1}{(377)^2(10^{12})\,(30)\,(10^{-12})}\left[1 + \frac{(0.6655)^2}{8} + \frac{3(0.0885)^2}{8}\right] = 0.2475 \times 10^{-6}\ hy$$

$$\lambda_3 = \frac{1}{(377)^4(10^{24})\,(6 \times 10^{-12})\,(30 \times 10^{-12})} = 0.275 \times 10^{-12}$$

$$k = \sqrt{1 - \frac{0.275 \times 10^{-12}}{1.365 \times 10^{-6} \times 0.2475 \times 10^{-6}}} = 0.43$$

Summary of Appendix

The transformers were designed using these constants, thereby obtaining the results outlined in the body of this report.

Due to manufacturing tolerances, the values of input resistance (R_{iep}) encountered in practice will vary. If the bandwidth of the amplifier must be maintained within very close tolerances, then resistance can be shunted across the input to the various stages where it is necessary to obtain the exact value of input resistance that was calculated. The majority of 3N35's have an input resistance below the 133 ohms chosen, which results in a slightly wider bandwidth and somewhat lower gain per stage than was calculated.

References

[1.] Cornelison, B., and Adock, W. A., "Transistors by Grown-Diffused Technique," WESCON Meeting, 21 August 1957.

[2.] Wallace, R. L., Schimpf, L. G., and Dickten, E., "A Junction-Transistor Tetrode for High Frequency Use," *Proc. IRE, Vol. 40*, pp. 1395-1400; November, 1952.

[3.] Brower, W. C., and Earhart, C. E., "70 Megacycle Silicon Transistor," Third Annual Electron Devices Meeting of the IRE, Washington, D. C., 1 November 1957.

[4.] Webster, R. R., "Silicon Tetrode Transistors for the 5-40 mc Region," National Conference on Aeronautical Electronics, Dayton, Ohio, 14 May 1956.

[5.] Webster, R. R., and Stewart, R. F., "Some Circuit Applications of Silicon Tetrodes," WESCON Meeting, 24 August 1956.

[6.] Valley, G. E., Jr., and Wallman, H., Vacuum Tube Amplifiers, McGraw-Hill Book Co., New York, 1948.

[7.] Lawson, J. L., and Stone, A. M., "The Double-Tuned Circuit With Transitional Coupling," Radiation Laboratory Report No. 784, M.I.T., Cambridge, Massachusetts, 8 October 1945.

Temperature Effects and Stability Factor

A. W. CARLSON*

This article treats the effects of temperature variations on transistor parameters. The exponential variation of the saturation current, I_{co}, with temperature is given. The effects of temperature change on the common-emitter input and output characteristics and on the transfer characteristic are shown. An "overbiased" amplifier with its equivalent circuit is used to illustrate the effects of various biasing arrangements on thermal stability. A table summarizes the effectiveness of these biasing schemes. A factor dI_C/dT is given in this table which permits prediction of change in collector current with changes in temperature. The relationship of this factor to Shea's stability factor is given.

THE SKETCHES of the transistor characteristics shown in previous articles of this series were for a constant temperature and are as usually presented by the manufacturer (although it is not likely that data for all three configurations would be supplied). It is important that the effects of operation at other temperatures on transistor characteristics be considered.

It should be mentioned that the plotting of characteristics of an actual transistor at a constant junction temperature must be done rapidly since in traversing regions of high power dissipation the transistor will become heated. For example, in obtaining a $V_c - I_c$ curve for a constant I_E, the curve should be plotted in a much shorter time than the thermal time constant of the transistor in order that the junction temperature remain essentially constant. The thermal time constants of power transistors are of the order of milliseconds, which means that in practice the characteristic curves at a constant junction temperature must be obtained electronically. The frequency response of the transistor puts an upper limit to the rate at which the characteristic curves may be plotted. The characteristics of the transistor, when traced out slowly and junction temperature allowed to vary, will be considered later.

Although all the transistor parameters are functions of temperature to varying degrees, these may be considered as second order effects in comparison with the exponential variation of the saturation currents (I_{C0}, I_{E0}, I_{CS} etc.). I_{C0} as a function of temperature may be represented as

$$I_{C0} = I_{C01}\, e^{\phi \Delta T} \qquad (1)$$

where I_{C01} is I_{C0} at some reference temperature T_0, ΔT is $T - T_0$ (i.e., the temperature rise in degrees centigrade above the reference temperature), ϕ is a coefficient which is largely a function of the energy gap voltage of the semiconductor material and is of the order $.07 - .08/°C$ for germanium. I_{C0}, therefore, roughly doubles in value for each 10°C rise in temperature.

*This article is part of a project undertaken by Mr. Carlson for CBS-Hytron, while a member of its semiconductor applications engineering department, to produce a series of articles covering transistor parameters and circuitry and has been released by CBS-Hytron for publication in SEMICONDUCTOR PRODUCTS. Mr. Carlson is presently Director of Research for Transistor Applications, Inc.

Using Equation (1) in conjunction with the transistor equations and the representation of the transistor previously given†, allows determination of the effects of temperature changes. For example, in the common-base configuration, the constant I_E curves in the active region are given by

$$I_C = \alpha\, I_E + I_{C01}\, e^{\phi \Delta T} + V_C/r_C. \qquad (2)$$

From Eq. (2) it is seen that a change in temperature is reflected in the $V_C - I_C$ curves for I_E constant as a simple shift parallel to the current axis by an amount $I_{C01}\,[1 + e^{\phi \Delta T}]$

The $V_C - I_C$ for I_B constant (common-emitter characteristic) curves are shifted in a similar manner, but by an amount $(\beta+1)\; I_{C01}\; (1+e^{\phi\Delta T})$. Thus a given change in temperature produces a much greater shift in the I_B constant curves than for the I_E constant curves. The effect of a temperature change on the common-emitter output characteristic is illustrated in *Fig. 1*.

Fig. 2 shows the effect of temperature changes on the collector current-emitter (or base) voltage transfer

† See "Static Characteristics of Transistors," *Semiconductor Products*, June 1959.

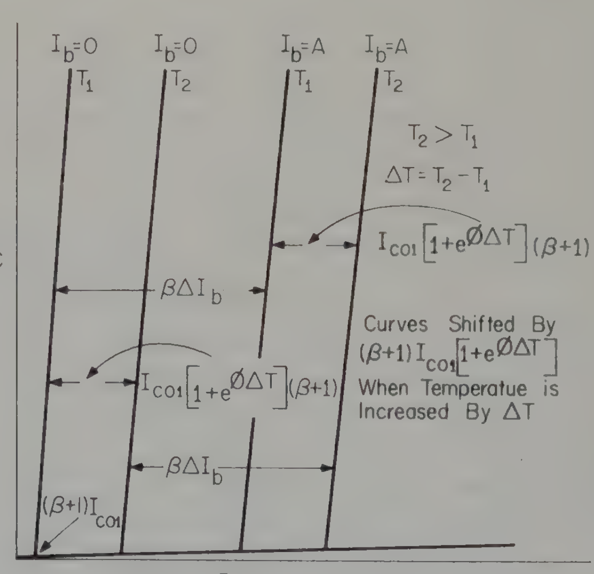


Fig. 1—Effect of temperature change on common emitter output characteristic with I_b as the running parameter.

characteristic. In obtaining the results shown, the variation of $\wedge$, the symbol used for q/kT, (and which is inversely proportional to absolute temperature) with temperature has been neglected as it is small for small changes about room temperature. The principal effect of a temperature change is to displace the transfer characteristic as indicated. In order to hold the collector current constant, the base or emitter bias voltage should be decreased at the rate of roughly 2 millivolts per degree increase in temperature.

The effects of temperature variation on the common-emitter input characteristic are shown in *Fig. 3*. Here, as with the transfer characteristic, the principal effect of temperature variation is a displacement of the characteristic parallel with the V_B axis. The common-base input characteristics are also shifted in a similar manner with the shift at constant I_E given by

$$\frac{dV_E}{dT} / I_E = -\left[\frac{\phi\,(I_E+I_{ES})\,(1+\wedge\, r_{bb'}\, I_{C0}) - \phi I_{ES}}{\wedge(I_E + I_{ES})}\right]$$

For emitter currents large with respect to I_{ES}, this reduces to

$$\frac{dV_E}{dT} / I_E \approx -\frac{\phi}{\wedge}\,(1 + \wedge\, r_{bb'}\, I_{C0})$$

and for low values of I_{C0} becomes approximately $-\frac{\phi}{\wedge}$.

An important consideration in transistor applications is the effect of temperature on *d-c* bias currents. It would be desirable for the bias currents to be independent of temperature variation, or, at the very least, sufficiently so to avoid conditions leading to thermal runaway, wherein an increase in temperature causes an increase in dissipation leading to a further increase in temperature in a regenerative manner until the transistor is destroyed. In *Fig. 4* is shown a biased amplifier and its *d-c* equivalent circuit representing the bias conditions. The biased amplifier of *Fig. 4* is not intended to be a typical arrangement — in fact it might be termed an "over-biased" amplifier. Its purpose is to show how the various elements in the equivalent circuit might logically come about and includes practically all of the conventional biasing schemes. R_B may be interpreted as the *d-c* resistance in the base circuit, R_E as the *d-c* resistance in the emitter circuit, and R_C as the *d-c* resistance in the collector circuit. For example, R_C might represent the *d-c* resistance of a transformer winding (and thus might be negligible) or, with no transformer in the collector circuit, might represent a *d-c* load resistor. The resistor R_F coupling collector to base is part of a biasing scheme sometimes used with resistance coupled circuits and provides negative feedback. In obtaining the equivalent circuit of *Fig. 4*, it has been assumed that R_F is much greater than $r_{bb'}$ so that it may appear in parallel with the leakage resistance r_c. Thus the equivalent circuit of *Fig. 4* represents most bias conditions where the presence of the various external elements (R_B, R_E, R_C and R_F) may be present or absent in various combinations. In *Fig. 5* some typical bias arrangements are shown; it may be seen that all reduce to the *d-c* equivalent circuit of *Fig. 4*.

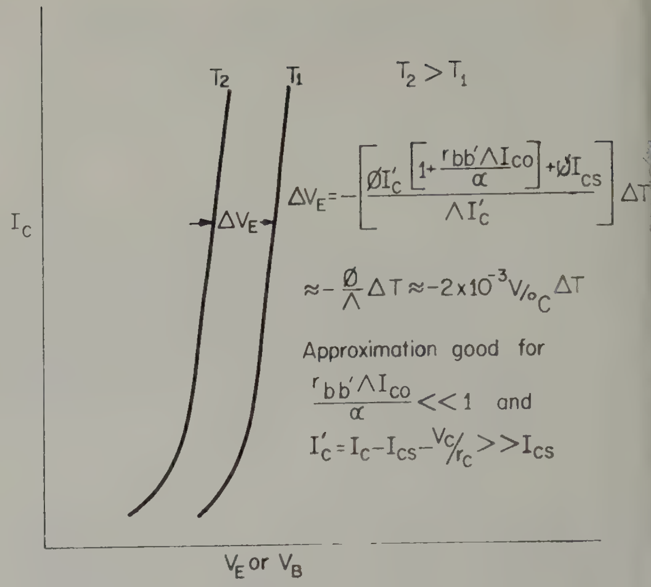


Fig. 2—Transfer characteristic temperature effects.

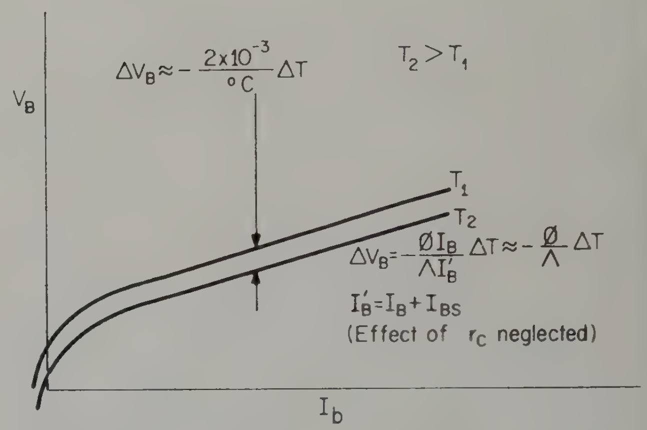


Fig. 3—Effect of temperature variation on common emitter input characteristics.

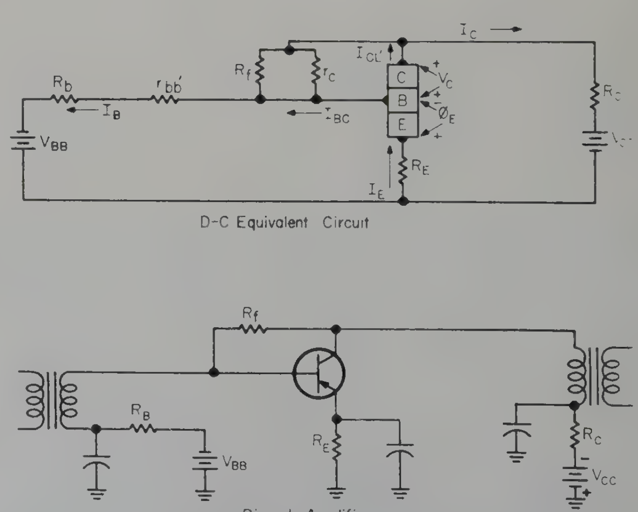


Fig. 4—Biased amplifier and D-C equivalent circuit.

Examination of the equivalent circuit of *Fig. 4* reveals that the presence of R_B is equivalent to increasing $r_{bb'}$ to $(R_B + r_{bb'})$ and the effect of R_F is the same as if r_c were replaced by $\frac{r_c \times R_F}{R_F + r_c}$ since R_F shunts r_c. When R_F is present in the circuit the current I_C shown in the equivalent circuit is not the actual transistor collector current but is the collector current flowing in a modified transistor, i.e., a transistor having a lower value of leakage resistance. This point is mentioned because in some derivations of temperature effects, R_F is handled differently. In *Fig. 4*, I_C may be regarded as the *d-c* load current which, when R_F is absent, becomes identical with the collector current.

The equations applying to *Fig. 4* are

$$V_C = V_{CC} - R_C I_C \qquad (3a)$$

$$\phi_E = V_{BB} - \left[\frac{r_{bb'} + (\beta+1) R_E}{\beta}\right] I_C + \frac{I_{C01}}{\alpha} e^{\phi\Delta T} \left[r_{bb'} + R_E\right] + \frac{V_C}{\alpha r_c}\left[r_{bb'} + R_E\right] \qquad (3b)$$

and

$$I_C = I_{CE1}\, e^{\Lambda\phi_E + \phi\Delta T} + I_{CS1}\, e^{\phi\Delta T} + V_C/r_c \qquad (3c)$$

In Equations 3a, 3b and 3c, R_B and R_F are neglected and are to be accounted for by modifying $r_{bb'}$ and r_c as mentioned before. I_{CE} and I_{CS} are $\frac{\alpha_1 I_{C0}}{1 - \alpha N \alpha_1}$ and $\frac{(1-\alpha_1) I_{C0}}{1 - \alpha N \alpha_1}$ respectively. The subscripts "1" refer to values at the reference temperature and values without subscripts are those at the existing temperature.

The change in I_C for a small change in temperature is given by

$$\frac{dI_C}{dT} = \frac{\phi I_{C'}\left[1 + \frac{\Lambda I_{C0}}{\alpha}(r_{bb'} + R_E)\right] + \phi I_{CS}}{1 + \Lambda I_{C'}\left[\frac{r_{bb'} + (\beta+1) R_E}{\beta} + \frac{R_C}{r_c}\left(\frac{r_{bb'} + R_E}{\alpha} + \frac{1}{I_{C'}\Lambda}\right)\right]} \qquad (4a)$$

where $I_{C'} = I_C - I_{CS} - V_C/r_c$. When I_C is large with respect to I_{CS} and V_C/r_c, $I_{C'}$ approaches I_C and Equation (4a) may be written

$$\frac{dI_C}{dT} = \frac{\phi I_C\left[1 + \frac{\Lambda I_{C0}}{\alpha}(r_{bb'} + R_E)\right]}{1 + \Lambda I_C\left[\frac{r_{bb'} + (\beta+1) R_E}{\beta} + \frac{R_C}{r_c}\left(\frac{r_{bb'} + R_E}{\alpha} + \frac{1}{\Lambda I_C}\right)\right]} \qquad (4b)$$

Approximations appropriate to various conditions of operation are listed in Table 1. Referring to this table one may examine the effectiveness of the various biasing schemes. For condition (b) where I_{C0} is small, the sensitivity to temperature change is reduced by increasing $r_{bb'}$ but as $r_{bb'}$ becomes large or as I_{C0} is increased condition (d) is approached where I_C is very dependent on temperature. The situation is improved when emitter resistance R_E is added to the circuit as shown in condition (f), corresponding to condition (d), where for large values of R_E relative to $r_{bb'}$, the sensitivity is reduced by a factor of approximately β.

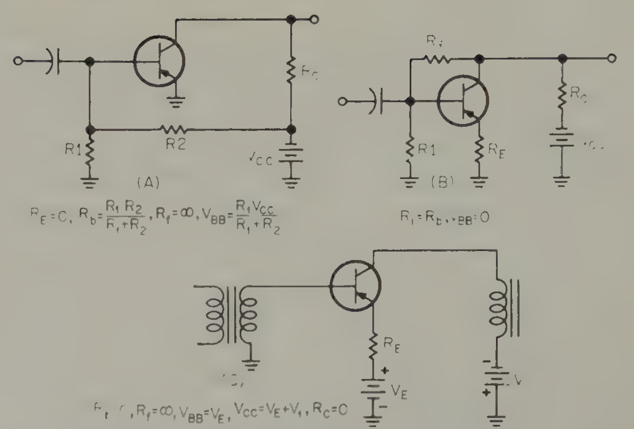


Fig. 5—Some bias arrangements and relationships with respect to Fig. 4.

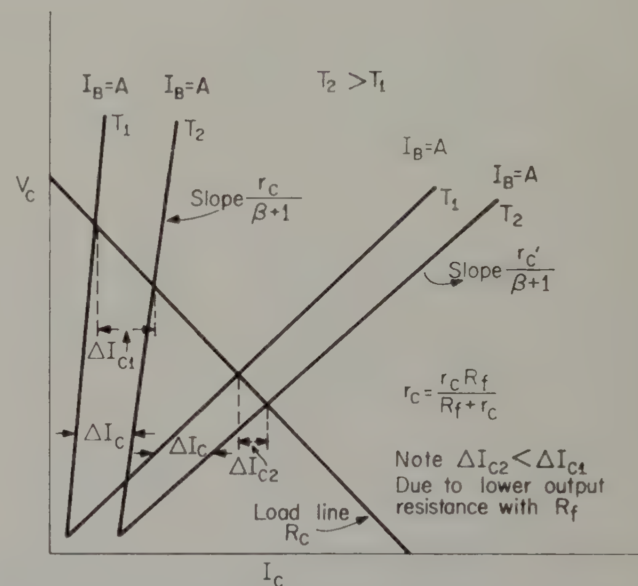


Fig. 6—Effect of R_f in reducing sensitivity of load current to temperature change.

The use of a feedback resistor R_F may also be quite effective in stabilizing the load current. This of course is effective only when there is *d-c* resistance in the collector circuit and would not be applicable in circuits using a transformer connected directly to the collector supply voltage. Examination of condition (h) applying at high values of I_{C0} (high temperature) shows that the sensitivity of load current to temperature changes may be quite small depending on the ratio r_c/R_C. The temperature sensitivity is reduced by making r_c small (R_F small) and increasing R_C. This type of compensation may be regarded as reducing the leakage resistance of the transistor and thus "spoiling" the transistor in the sense that a high leakage resistance is usually held desirable. The effect is an equivalent transistor having a lower output resistance in the active region. The stabilizing effect along a resistive load line may be shown graphically as in *Fig. 6*. The reduction in gain produced

Table I
Temperature sensitivity and stability factors for various bias conditions.

CONDITIONS	dI_C/dT
(a) $R_E = 0,\ R_C = 0,\ \dfrac{\wedge I_C r_{bb'}}{\alpha} \ll 1$	$\approx \phi I_C \left[1 + \dfrac{\wedge I_{C0}}{\alpha} r_{bb'}\right] \rightarrow \phi I_C,\ \dfrac{\wedge I_{C0} r_{bb'}}{\alpha} \ll 1$
(b) $R_E = 0,\ R_C = 0,\ \dfrac{\wedge I_C r_{bb'}}{\beta} \gg 1\ \dfrac{\wedge I_{C0} r_{bb'}}{\alpha} \ll 1$	$\approx \dfrac{\phi \beta}{\wedge r_{bb'}}$
(c) $R_E = 0,\ R_C = 0,\ \dfrac{\wedge I_C r_{bb'}}{\beta} \gg 1$	$\approx \dfrac{\phi \left[1 + \dfrac{\wedge I_{C0}}{\alpha} r_{bb'}\right] \beta}{\wedge r_{bb'}}$
(d) $R_E = 0,\ R_C = 0,\ \dfrac{\wedge I_C r_{bb'}}{\beta} \gg 1,\ \dfrac{\wedge I_{C0}}{\alpha} r_{bb'} \gg 1$	$\approx \dfrac{\phi \beta I_{C0}}{\alpha} = \phi (\beta + 1) I_{C0}$
(e) $R_C = 0,\ \dfrac{\wedge I_{C0}}{\alpha} (r_{bb'} + R_E) \ll 1$ $\wedge I_C \dfrac{[r_{bb'} + (\beta+1) R_E]}{\beta} \gg 1$	$\approx \dfrac{\phi \beta}{\wedge [r_{bb'} + (\beta+1) R_E]} \rightarrow \dfrac{\phi \alpha}{\wedge R_E},\ R_E (\beta+1) \gg r_{bb'}$
(f) $R_C = 0,\ \dfrac{\wedge I_{C0}}{\alpha} (r_{bb'} + R_E) \gg 1$ $\wedge I_C \dfrac{[r_{bb'} + (\beta+1) R_E]}{\beta} \gg 1$	$\approx \dfrac{\phi I_{C0} (r_{bb'} + R_E) (\beta+1)}{r_{bb'} + (\beta+1) R_E} \rightarrow \phi I_{C0},\ R_E \gg r_{bb'}$
(g) $R_E = 0,\ \dfrac{r_{bb'}}{\beta} \ll \dfrac{R_C}{r_c} \left(\dfrac{r_{bb'}}{\alpha} + \dfrac{1}{\wedge I_C}\right)$ $\dfrac{\wedge I_{C0} r_{bb'}}{\alpha} \ll 1,\ \wedge I_C \dfrac{R_C}{r_c} \left(\dfrac{r_{bb'}}{\alpha} + \dfrac{1}{\wedge I_C}\right) \gg 1$	$\approx \dfrac{\phi \alpha r_c}{\wedge R_C \left[r_{bb'} + \dfrac{\alpha}{\wedge I_C}\right]}$
(h) $R_E = 0,\ \dfrac{1}{\wedge I_C} \ll \dfrac{r_{bb'}}{\alpha},\ \dfrac{\wedge I_{C0}}{\alpha} r_{bb'} \gg 1$ $\dfrac{r_{bb'}}{\beta} \ll \dfrac{R_C r_{bb'}}{\alpha r_c},\ \dfrac{\wedge I_C R_C r_{bb'}}{\alpha r_c} \gg 1$	$\approx \dfrac{\phi I_{C0} r_c}{R_C}$

Note: When R_b is present add to $r_{bb'}$. When R_f is present, change r_c to $\dfrac{r_c R_f}{r_c + R_f}$ To obtain stability factor S divide $\dfrac{dI_C}{dT}$ by $\phi\ I_{C0}$.

by addition of R_F may be confined to *d-c* bias currents by preventing *a-c* signals from reaching the base such as by tapping R_F and by-passing the tap to ground or by inserting a choke in series with R_F.

Another useful quantity is dI_C/dI_{C0}, called the stability factor, S, by Shea. The stability factor permits prediction of changes in collector current for various bias schemes due to changes in I_{C0} such as might occur in replacing a transistor with a similar unit having a different I_{C0} or when there is a temperature change. Although the stability factor is often used to consider temperature effects it appears preferable to use dI_C/dT since relating the stability factor to a change in temperature requires two steps: first, the change in temperature must be converted to an equivalent change in I_{C0} and second, the change in I_C must be determined from the change in I_{C0}. This procedure makes visualizing the effect of a given temperature change difficult due to the exponential relationship between I_{C0} and temperature change.

The stability factor $S = \dfrac{dI_C}{dI_{C0}}$ and $\dfrac{dI_C}{dT}$ are simply related by

$$S = \frac{dI_C}{dI_{C0}} = \frac{dI_C}{dT} \times \frac{dT}{dI_{C0}}. \tag{5a}$$

From Equation (6), dT/dI_{C0} is $1/\phi\ I_{C0}$ permitting (5a) to be written as

$$S = \frac{dI_C}{dI_{C0}} = \frac{1}{\phi\ I_{C0}} \times \frac{dI_C}{dT}. \tag{5b}$$

To obtain the stability factor it is only necessary to divide Equations (4) and dI_C/dT in Table I by $\phi\ I_{C0}$.

Note that a low value of stability factor is desirable meaning that I_C should not change greatly with I_{C0}. Because of the emphasis sometimes placed on the desirability of low values, several precautions are necessary in interpreting the stability factor:

(1) it should be noted that S is not a constant as is sometimes assumed and

(2) extremely large values of S may hold for some conditions of operation yet the circuit may not be overly sensitive to temperature changes.

To illustrate, consider conditions (b) of Table I where the stability factor is $\frac{\beta}{\wedge\ r_{bb'}\ I_{C0}}$ applying when $\frac{\wedge\ I_C\ r_{bb'}}{\beta} \gg 1$ and $\frac{\wedge\ I_{C0}\ r_{bb'}}{\alpha} \ll 1$. Assuming $r_{bb'} = 1000$ ohms, $I_C = 10$ milliamperes, $\wedge = 40$ volts $^{-1}$, $\beta = 20$, $\phi = .1$ and $I_{C0} = 2$ microamperes, yields a stability factor of 250.

At first glance a stability factor of this magnitude may appear frightening until it is recalled that it is applicable to conditions where I_{C0} is very small (as at low temperatures). For the same conditions $dI_C/dT = .05 \times 10^{-3}$ and a 10°C increase in temperature would increase I_C by one-half a milliampere. A 10°C increase in temperature doubles I_{C0} giving a $\Delta\ I_{C0}$ of 2 microamperes which when multiplied by the stability factor of 250 also gives an increase in I_C of one-half a milliampere.

Under conditions (f) of Table I, when I_{C0} and I_C are relatively large, S approaches $\frac{(\beta + 1)\ (r_{bb'} + R_E)}{r_{bb'} + (\beta + 1)\ R_E}$, the stability factor as given by Shea. The differences between Shea's stability factor and those given here come about due to a simplifying assumption used by Shea, namely, that the small signal equivalent circuit applies.

References

1. H. C. Lin and A. A. Barco, "Temperature Effects in Circuits Using Junction Transistors," Transistors I, RCA Laboratories, Princeton, N. J., 1956.
2. Richard F. Shea, Editor, "Principles of Transistor Circuits," John Wiley and Sons, Inc., N. Y., 1953.
3. J. J. Ebers and J. L. Moll, "Large Signal Behavior of Junction Transistors," *Proc. IRE*, Vol. 42, December, 1954.

Silicon Carbide and Its Use in High Temperature Rectifiers

H. C. CHANG*

Because of its large band gap and high chemical stability, silicon carbide is recognized as one of the best semiconductors for high temperature applications. This article describes briefly the early work on the preparation of single crystals of semiconductor quality and the fabrication of grown junction rectifiers capable of operation at an ambient temperature of 500 degrees C.

SILICON CARBIDE is one of the few large energy gap semiconductors (2.86 e.v.) that exhibits both p- and n-type conductivity. The increasing demand for semiconductor devices capable of high temperature operation has aroused great interest in the investigation of this material.

Silicon carbide crystallizes in two basic forms, cubic and hexagonal. They have no liquid phase at atmospheric pressure. The cubic form is designated β-SiC and is formed about 2000 degrees centigrade in the vapor phase. The hexagonal form appears in at least six modifications of a basic hexagonal structure designated from α-I to α-VI. α-SiC is formed in the temperature range from 2400 degrees C to 2600 degrees C. The conductivity type of α-SiC can be detected by the crystal color. Blue crystals show p-type conductivity, and green crystals show n-type conductivity. A comprehensive literature survey of silicon carbide is given by Harman and Mixer[1] and by Halden and Smiley.[2]

α-SiC has been commercially produced for many years, but only recently have single crystals of semiconductor quality been produced in the laboratory; first by Lely of Philips Research Laboratories in Europe[3] and later by Chang and Kroko[4] and Hamilton[5] of Westinghouse Electric Corporation in this country. Chang and Kroko have improved Lely's method by growing single crystal platelets from the vapor phase on a thin graphite substrate at about 2500 degrees C, using a mixture of pure silicon and carbon as starting materials.

As a result of studies of vapor growths and nucleation mechanisms, significant progress has been made on the control of crystal size, perfection, and purity. Recent development on techniques of producing large area planar p-n junctions and low resistance contacts on silicon carbide has resulted in rectifiers with a

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leakage current of 5 ma at 300 volts and forward drops as low as 5 volts at 500 ma. These rectifiers have been assembled, encapsulated, and operated at temperatures in excess of 500 degrees C. Rectifiers with a rating of 150 volts and 1 ampere have been made in the laboratory. The following sections will describe briefly the principles and the methods of crystal preparation and device fabrication.

High Temperature Furnace

Since silicon carbide decomposes at high temperatures, sealed containers should be used for growing crystals. However, there are no materials available at present for constructing a container which will not react with silicon carbide and will remain gas-tight at about 2500 degrees C. A practical solution is that of using silicon carbide itself as a container. Growth of crystals occurs inside a cavity formed in a bulk silicon carbide mass. The cavity sustains an equilibrium of the silicon-carbon-silicon carbide system, and the vapor pressure is maintained at a supersaturated state by virtue of the constant decomposition of the surrounding material at a temperature greater than that of the cavity. Although the cavity is not a sealed container, an equilibrium vapor pressure condition can be achieved in this way for the growth of large single crystals. In Lely's furnace, as well as in commercial furnaces, silicon carbide single crystals have been grown in cavities by this principle.

Because crystal growth depends on proper supersaturation of the vapor and the ability of the crystal to dissipate the heat of vaporization of the condensed molecules or atoms, temperature and, more particularly temperature gradients around the cavity are very important and, in fact, constitute the only controllable parameters in the process of growth.

Resistance-heated furnaces using graphite as the heating element which provide the necessary temperature gradients around the growth cavity have been developed. One such furnace of the Lely-type is shown schematically in *Fig. 1.*

The heater is a hollow carbon tube slotted so as to divide the cylinder into halves jointed at one end. Current then may be passed in one side through the electrodes and out the other. The hot zone of the furnace is located near the free end of the heater where the current path reverses direction. By making the heater in this manner, the major heat loss takes place at one end and a minimum of power is required for a given temperature. No provision need be made for the longitudinal expansion of the heater. Insulation is provided by finely powdered carbon loosely placed in the surrounding container. To keep from shorting the heater across the slot, a graphite baffle is hung on the outside of the heater from a ridge at the top. The inside of the heater is protected from silicon vapor by a graphite liner which also serves to hold the crucible at the proper position in the hot zone. The cavity is located at the center of the crucible and is surrounded by silicon carbide or a powdered mixture of silicon and carbon. One or more carbon sighting tubes which open near the heater are constantly supplied with argon to keep the sighting channel clear for measuring the temperature through the glass windows. Another gas tube used for doping is located inside the heater.

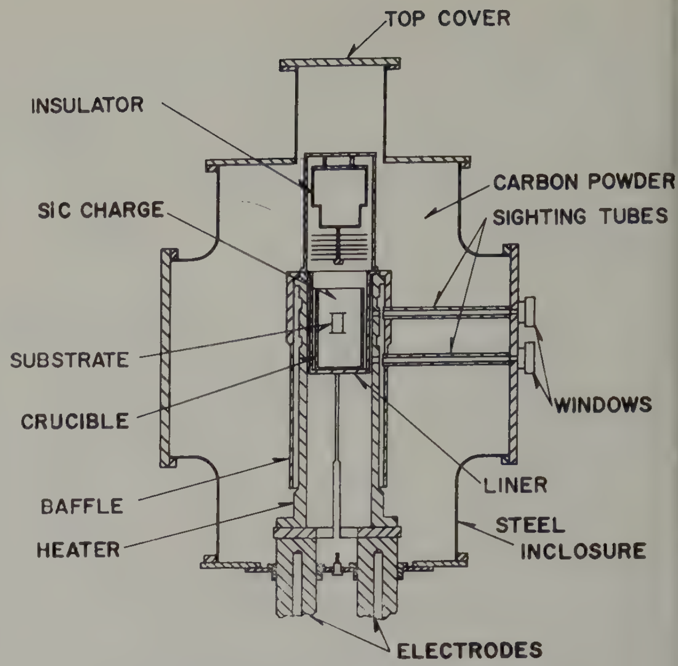


Fig. 1—Schematic of a Lely-Type furnace.

In order to obtain a temperature reading as close to the actual temperature of the crucible as possible, the graphite sighting tube allows visual observation of the outside of the liner through a hole on the heating element. It is not practical to view the crucible proper because of the high density of silicon carbide vapor in that area and the consequent clogging of the sight tube by condensation of this material.

The power consumption of these furnaces varies somewhat depending upon the quality of the electrical connection to the heater and the thermal conductivity of the insulating powdered carbon.

Crystal Growth Studies

Controlled growth of large silicon carbide single crystals of high perfection is possible only if the growth conditions are well understood. The investigation of the mechanism of silicon carbide crystal growth from the vapor phase constitutes, therefore, one of the main objectives of the development. In general, the growth pattern of silicon carbide crystals in the crucibles can be shown in *Fig. 2.*

Study of the cross section of the growth path reveals that the underlying bulk silicon carbide crystallizes in the form of needles along definite paths or lines culminating in crystals which grow into space following the same paths. Ultimately, many nucleations or crystals are produced, and a certain number reach a well-developed state to form large but mostly imperfect crystals.

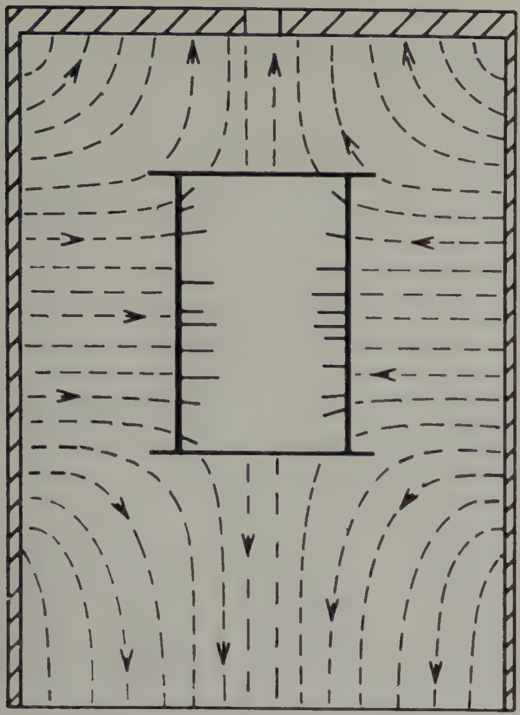


Fig. 2—Growth pattern.

Fig. 3—Cross section of the crucible.

The needle-like structure appears to be the result of the formation of nucleation and growth in a highly supersaturated solution. The needles are aligned in the direction of heat flow or temperature gradient. The mass of the silicon-rich region between the needles vaporizes and leaves an empty space. *Fig. 3* shows schematically an enlarged view of the cross section of the crucible in *Fig. 1.* Single crystals are shown as solid short lines attached on the surface of the cavity. The furnace in which the crucible is heated is such that the sides of the crucible are hot and the ends are cool, and, hence, heat flows essentially along the dashed arrow lines of the illustration. The resemblance between these schematic heat flow lines and the actual growth pattern produced in the laboratory, as shown in *Fig. 2,* is striking.

After having emerged from the needle-like substrate, individual crystals are observed to display a well-shaped hexagonal face roughly parallel to an extension of the growth lines. Furthermore, it is noted that in practically all cases the normals to these faces are parallel or nearly parallel for all crystals in a given cluster. This phenomenon may be observed in *Fig. 2.*

Assuming a crystal already grown to some significant size, it is possible to determine the mechanism by which the heat of vaporization of incoming molecules is dissipated. There are three possibilities: Radiation from the faces of the crystal, conduction to the substrate from which the crystal grows, or conduction and convection to the gas inside the growth cavity. From the designed temperature gradient of the crucible and also because the nucleation substrate can and often does support growth at a temperature where new nucleations cannot form, it is reasonable to assume that the substrate can be hotter than the crystal proper and, hence, can conduct no heat away from the crystal.

If a significant amount of the heat of condensation were conducted to the gas in the growth cavity, one would expect to find equal numbers of crystals oriented in all directions in all charges since no single orientation would be capable of dissipating heat to the gas any better than any other. Experience has shown that far more crystals and certainly the largest ones grow with plane faces parallel to the hot zone normals (i.e., parallel to the top and bottom of the crucible as shown in *Fig. 3*). When a large number of crystals are nucleated and grown in a cavity, it is observed that many are oriented in an apparent contradiction to this rule. However, the contradiction is not real for it is entirely possible for one crystal to radiate energy to several others rather than to the cold object directly. Simple computations have shown that the amount of energy radiated per unit temperature difference at temperatures in the vicinity of 2400 degrees C considerably exceeds that removed by conduction or convection. Since the energy radiated is a function of the difference of the fourth powers of the temperatures of the high and low temperature regions and is proportional to the area of the radiation and receiving sources, one would expect crystals whose broadest areas are aligned parallel to the cold sources to be capable of radiating more energy and, hence, to grow more in a fixed period of time.

If the temperatures on the two cold sides of crystal platelets are exactly equal, one would expect platelets of uniform thickness. Otherwise, growth may proceed more rapidly on the colder side giving rise to a stepped or pyramid crystal as found in commercial charges

and some of those grown in a Lely-type furnace.

By balancing the heat transfer mechanisms discussed previously, the thickness of the crystal platelets can be controlled. If the rate of radiated heat dissipation is smaller along the flat faces, the platelets will grow thinner. This can be realized if the temperature of the cold end of the crucible is made closer to the temperature of the hot side.

Obviously, well-shaped single crystal platelets can be grown only if a limited number are permitted and, therefore, in addition to the control of temperature for growth, it is necessary to make use of a nucleation substrate and a suitable temperature program for the control of nucleations.

Because of the temperatures involved and the high reactivity of silicon vapor, graphite was considered to be the most likely prospect. The use of a graphite substrate for restricting nucleations offered other advantages for control of the growth process; the graphite substrate which has a higher thermal conductivity than silicon carbide forms a smooth isothermal surface and permits control of the temperature gradient within the growth region. In addition, when a thin-wall graphite tube is used as a substrate, the tube forms a rigid cavity wall and permits the use of powdered starting materials. However, the wall thickness of the graphite tube should not obstruct the necessary diffusion of silicon carbide vapor and disturb the normal heat flow patterns on the crystal growth region.

When the furnace is heated up, the vapor in the cavity gradually becomes supersaturated to such a degree that nucleation starts on the graphite substrate. The heterogeneous nucleation of silicon carbide crystals on graphite or on other substrates is presumed to occur by the formation of small cap-shaped critical nuclei of the order of 10 to 100 atoms, whose size is increased by the migration of atoms or molecules along the surface of the substrate after impinging on that surface. As the furnace is further heated up, the temperature of the substrate may become high enough so that the degree of supersaturation of the vapor may not favor the formation of new nucleation centers on the graphite substrate. This low degree of supersaturation maintains the oriented growth of crystals already nucleated on the graphite substrate. In fact, this is one of the theoretical conditions for growing large and perfect crystals.

The nucleation period and growth rate have been studied experimentally by the color marking technique in which nitrogen is admitted periodically into the furnace to produce green bands on the growing crystals. It has been found that crystals are nucleated within a certain period of approximately ten minutes at the very beginning of the run. The variation of crystal size is a result of the differences in growth rate of individual crystals. It is, therefore, possible to speculate on ways in which nucleation and growth might be controlled. The number of nucleations occurring during the nucleation period can be considered as a function of the degree of supersaturation and the length of time. Therefore, the total number of nucleations is dependent upon the time required for the furnace to pass through a certain temperature range. The temperature during the growth period should be maintained steady and high enough in order to keep a low degree of supersaturation for the growth of larger crystals with high degrees of perfection.

Control of Purity and Doping

The preparation of single crystals for both pure research and device fabrication requires the control of impurity as well as perfection. The growth of silicon carbide crystals from the vapor phase in a nonsealed, high temperature system presents many technical difficulties in the control of impurity.

The crystal purity depends on three major factors; contamination of the furnace, purity of the starting materials, and temperature and growth rate of the crystal. The main sources of impurities in the Lely-type furnaces are the large quantities of carbon powder for thermal insulation. The huge mass of contaminated carbon powder should be isolated as much as possible from the heater and crucible. Otherwise, it provides a constant supply of impurities to the growth cavity. Any degassing process becomes almost ineffective since the fine powder has a large surface-to-volume ratio.

One of the obvious approaches to pure crystal production is that of utilizing purer starting material. Since silicon carbide has no liquid phase under normal pressures, it is impracticable, if not impossible, to apply the zone melting technique for the purification of silicon carbide. Although the method of recrystallization by sublimation for purifying silicon carbide is quite feasible, a more direct approach is the use of pure silicon and carbon as the starting material, since both materials can be obtained in a very pure form.

For most high temperature compounds, such as silicon carbide, the distribution coefficient for the impurity, defined as the concentration ratio in the solid to that in the vapor, is very small and decreases with the decreasing growth rate and increasing growth temperature. The segregation of impurity atoms from the growing crystal may, therefore, be controlled by the temperature distribution of the crucible.

Pure n-type silicon carbide platelets, transparent and colorless, having room temperature resistivities ranging from 10^6 to 10^7 ohm-cm have been produced using transistor-grade silicon and carbon as starting materials.

For device application, silicon carbide crystals should be properly doped. Boron and aluminum have been used as p-type, and nitrogen as n-type doping elements. Other doping elements have also been used. Aluminum and boron can be added to the charge material in the form of compounds such as B_2O_3, Al_2O_3, etc. In this way the distribution of impurities in crystals is not uniform, and doping is not under control. It is desirable to introduce the doping elements in the form of vapor. As reported by Lely, volatile com-

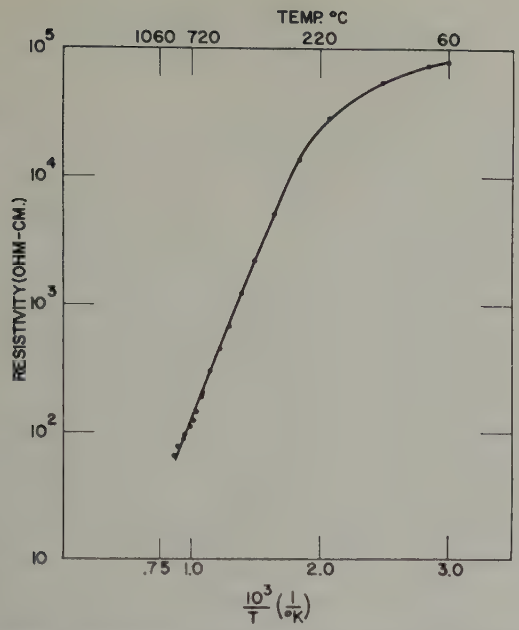


Fig. 4—Resistivity of high purity silicon carbide.

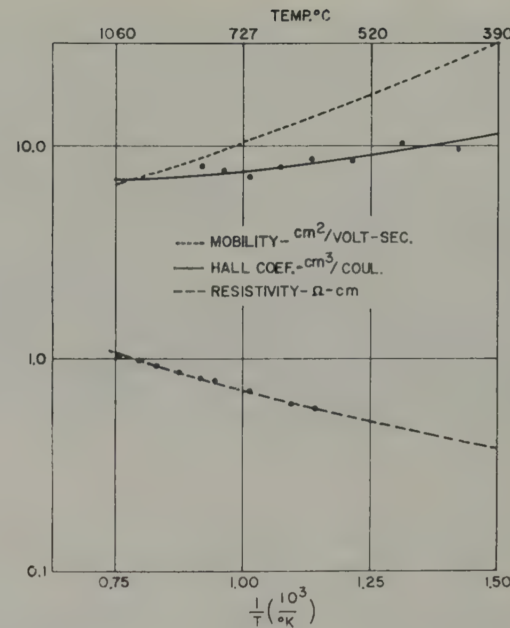


Fig. 5—Properties of n-type silicon carbide at operating temperatures of devices.

pounds, such as BCl_3, $AlCl_3$, PCl_3, etc., mixed with argon gas can also be used as doping materials. The vapor is introduced into the crucible region through the bottom center of the heater and homogeniously diffuses into the growth cavity. Types and concentrations of the impurity atoms flowing into the crucible region per unit time and the duration of doping can be controlled by varying the vapor pressure of the doping materials. The thermal conditions of the crucible should be maintained at a steady state during the entire growth period.

The reproducibility of doping silicon carbide depends, among other things, on the effectiveness of cleaning the furnace after each doping. The doping vapor should be confined to the crucible region and completely isolated from the heater and the carbon powder insulation.

Figure 4 and *Fig. 5* show typical curves of resistivity and Hall measurements of pure and doped n-type silicon carbide in the range of operating temperatures. The doped n-silicon carbide shows the predominant effect of decreasing mobility with temperature. The mobility varies approximately according to $T^{-1.7}$. Hall measurements on pure silicon carbide are not as reliable as on doped silicon carbide.

The rectifiers are fabricated from silicon carbide crystals containing grown junctions. These crystals are grown in a p-n-p or n-p-n structure.

For growing crystals of an n-p-n structure, the furnace charge contains aluminum in addition to the silicon and carbon so the silicon carbide crystals are highly doped p-type at the beginning of the growth period. After an initial period of crystal growth, as the aluminum content in the crystal is diminishing, nitrogen is added to the argon atmosphere in the growth cavity so that the crystals then start to grow with a nitrogen excess and become n-type.

In case crystals of a p-n-p structure are grown, the furnace charge contains only silicon and carbon. The argon flowing into the growth region contains nitrogen during the initial period of crystal growth. Finally, the nitrogen content in the argon is reduced to zero, and aluminum vapor is introduced into the argon atmosphere.

The material design of silicon carbide rectifiers is based on the assumption that the actual temperature of the rectifier is 150 degrees C higher than the ambient temperature of 500 degrees C. The average physical constants of silicon carbide at 650 degrees C are listed in Table I.

In principle, impurities produce imperfections in crystals during growth. It is, therefore, necessary to form nuclei containing a minimum amount of impurities and grow pure crystals to form the bulk material. Because of the difference of electron and hole mobil-

TABLE I

Band Gap	**2.66 ev**
Electron Mobility	**30 cm^2/volt-sec**
Hole Mobility	**2 cm^2/volt-sec**
Minority Carrier Lifetime	**10^{-8} μsec**
Thermal Conductivity	**0.05 cal cm/sec cm^2 °C**
Coefficient of Linear Thermal Expansion	**4.7×10^{-6} cm/cm °C**
Electron Diffusion Length	**15.4×10^{-5} cm**
Hole Diffusion Length	**4×10^{-5} cm**
Effective Mass of Electrons	**0.6 m_e**
Effective Mass of Holes	**1.2 m_e**
Electron Diffusion Constant	**2.4 cm^2/sec**
Hole Diffusion Constant	**0.16 cm^2/sec**
Intrinsic Carrier Concentration (N_i)	**$N_i^2 = 3.4 \times 10^{25}/cm^6$**
Diclectric Constant	**9.01×10^{-13} farads/cm**

Physical constants of α—SiC at 650° C

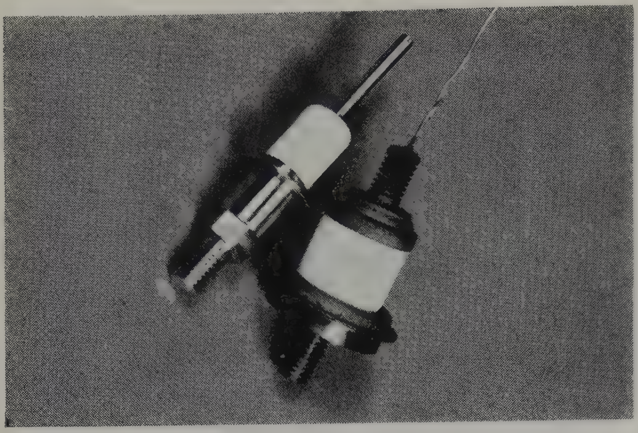


Fig. 6—Encapsulated silicon carbide rectifiers.

ities at 650 degrees C, it is preferable to have p-n junction formed by a lightly doped, n-type bulk material and thin layer of heavily doped, p-type material.

It is necessary to remove sections of the crystal and one junction before the rectification of the other can be observed. The junction edges of the crystal are removed with an ultrasonic cutter. One junction is lapped off and at the same time the thickness of the bulk layer is reduced to a minimum.

Before ohmic contacts are made, the crystals should be etched to remove the disturbed surface. Several molten salt pre-etchants similar to the one reported by Horn[6] can be used.

Attempts to provide silicon carbide with soldered ohmic contacts using silicon alloys as solders have been succesful. The operation is performed at temperatures from 1200 to 1800 degrees C. Molybdenum or tungsten may be chosen as electrode materials because their thermal expansions are close to silicon carbide. As reported by Hall[7], tungsten electrodes can be also directly fused to silicon carbide at about 1800 degrees C, producing strong mechanical contacts.

A lead and a heat sink are attached to the p- and n-layer, respectively. The heat sink also forms the base for encapsulation. It is understood that all metallic parts exposed to air should be chemically and physically stable at the operating temperature of the device and should have good electrical as well as thermal conductivities. Nickel, silver, and nickel clad copper are among those metals chosen for this application.

The unit should be etched to remove the conductive skin and leakage paths at the junction perimeter. Some electrolytes which are commonly used for etching silicon can be employed for etching silicon carbide. Care should be taken to avoid nonuniform etch since silicon carbide has a higher resistivity than silicon. The effectiveness of the postetch may be observed by reduction of blue spots around the junction edge when the rectifier is biased in the reverse direction.

Figure 6 shows the encapsulated silicon carbide rectifiers. The glazed alumina header provides a gas-tight seal at 650 degrees C.

There is at present a rather wide variation in rectifier characteristics, especially the reverse voltage and current. The leakage current is rather high and shows no saturation up to 150 volts. Some rectifiers with leakage currents of 5 ma at 300 volts and forward drops of 5 volts at 500 ma have been obtained. Rectification has been observed at temperatures in excess of 700 degrees C.

According to the theory of Sah, Noyce, and Shockley[8], the leakage current of a silicon carbide rectifier will not saturate and will be many orders of magnitude larger than that due to thermal generation of minority carriers. The current due to generation of carriers from traps in the space charge region of p-n junction accounts for the observed phenomenon. The phenomenon dominates in semiconductors, such as silicon carbide, with large energy gap, low lifetime, and low resistivity. The theoretical values of the leakage current are still much smaller than the observed, which differences are believed to be largely due to junction imperfections.

Acknowledgments

We would like to acknowledge that the work on materials reported here is supported in part by the Air Force Cambridge Research Center and that the device work is supported in part by the Wright Air Development Center. The author is grateful to many of his Westinghouse colleagues who participate in this silicon carbide development program and, in particular to Mr. L. Kroko and Mr. J. Ostroski.

References

[1] C. G. Harman and W. G. Mixer, Jr., "A Review of Silicon Carbide," No. BMI-748, Office of Technical Service, Washington 25, D. C., June 3, 1952.
[2] F. A. Halden and W. D. Smiley, Quarterly Technical Report No. 1 of Shockley Semiconductor Laboratory to Bureau of Ships under Contract NOBSR-72706 (1734F) Ser. 1734F-390, December, 1957.
[3] J. A. Lely, Berichte Deutschen Keram, Ges., 32, 229 (1955).
[4] H. C. Chang and L. J. Kroko, "Preparation of Silicon Carbide Single Crystals and Their Use in Rectifiers," presented at the Semiconductor Device Research Conference at Boulder, Colorado, July 15-17, 1957; also AIEE Conference, Paper 57-1131, Chicago, October 9, 1957.
[5] D. R. Hamilton, "The Preparation of Crystals of Hexagonal Silicon Carbide," presented at the New York meeting of the Electrochemical Society, May 1, 1958.
[6] F. H. Horn, Phil. Mag., 43, 1270 (1952).
[7] R. N. Hall, J. App. Phys. 29, 914 (1958); also "Alloyed Junctions to Silicon Carbide," presented at the Semiconductor Device Research Conference at Boulder, Colorado, July 15-17, 1957.
[8] C. T. Sah, R. N. Noyce, and W. Shockley, *Proc. I.R.E.*, 45, 1228-1243 (1957).

APPLICATIONS ENGINEERING DIGESTS

APPLICATION ENGINEERING DIGEST NO. 27

ransistor Choppers; Texas Instruments ic., Dallas, Texas.

The designer of a chopper amplifier iould consider the advantages of transtors over mechanical switches. In adtion to being small, transistors have w driving power requirements, a drive equency that can be varied widely, id long life expectancy.

Most limitations of transistor choppers rise because the transistor is not a perct switch; during the ON period the esistance between the switch terminals not zero and during the OFF period is not infinite. These resistances vary ith temperature and with the current ow through the device. Also the back ias that turns the transistor OFF cretes temperature dependent leakage urrents while the ON base current roduces stray voltages at the switch erminals.

quivalent Circuits

For the OFF condition, the equivalent rcuit of a low-level *p-n-p* transistor iopper is shown in *Fig. 27.1* where the lements are defined as follows:

$$I = \frac{I_S(1-\alpha_i)(1-e^{V_B\delta/T})}{1-\alpha_i\alpha_n}$$

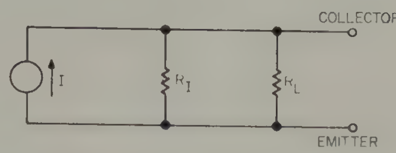


Fig. 27.1—"OFF" equivalent circuit

$$R_I = \frac{T(1-\alpha_i\alpha_n)e^{-V_B\delta/T}}{I_S}$$

R_L = ohmic leakage resistance usually a function of the surface condition of the semiconductor crystal)

I_S = true reverse-biased collector-base diode saturation current at T°K when $I_E = 0$ (does not include ohmic leakage currents)

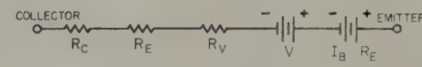
α_n = common-base emitter-to-collector current transfer function, or normal alpha

α_i = common-base collector-to-emitter current transfer function, or inverted alpha

V_B = switching drive voltage between base and emitter, (assuming a positive voltage for the forward-biased direction)

T = temperature in degrees Kelvin

δ = 8.616×10^{-5} joule/coulomb °K



WHERE $V = \frac{T(1-\alpha_i)(1-e^{-V_B\delta/T})}{\delta}$

$R_V = \frac{T\alpha_i(1-\alpha_i\alpha_n)}{I_B\,\delta\alpha_n}$

I_B = BASE CURRENT DRIVE

R_E = EMITTER BULK RESISTANCE (OHMIC)

R_C = COLLECTOR BULK RESISTANCE (OHMIC)

Fig. 27.2—"ON" equivalent circuit

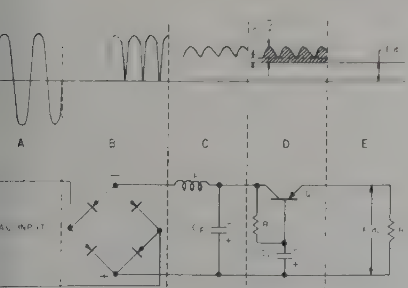
For the ON condition, the equivalent circuit of a low-level *p-n-p* transistor chopper is shown in *Fig. 27.2*. For *n-p-n* transistors, the direction of current flow I and the polarity of voltage sources V and I_BR_E are reversed.

Circle 148 on Reader Service Card

APPLICATION ENGINEERING DIGEST NO. 28

ower Transistor "Ripple Clipper" Filer For High Current D.C. Power Suply Use; Minneapolis-Honeywell Reguator Co., Minneapolis, Minn.

The power transistor can be used as a ery effective means of ripple removal n relatively high current power suplies. The energy contained in the ripple omponent of the power supply is disipated as heat by a power transistor acting as a controlled variable series resistance. The degree of ripple removal obtainable is determined by the gain of the transistor or transistors used and the time constant of the base biasing circuit. The amount of ripple energy that can be safely handled is limited by the thermal resistance of the transistor and the heat dissipator associated with it.



ig. 28.1—Basic transistor ripple cliper circuit and representative voltage wave forms.

Basic Ripple Clipper Circuit

The basic transistor ripple clipper circuit shown in *Fig. 28.1* illustrates the simplest form of application, and a representation of the voltage wave form at:

A. AC input
B. Rectifier output
C. Output of nominal LC filter section
D. Voltage across transistor referred to common positive (+)

E. Output of transistor ripple clipper. The shaded portion of the wave form at D shows the voltage across the transistor. This voltage times the average current through the transistor (I_{av}) represents the ripple energy dissipated as heat.

The transistor ripple clipper filter is not an energy storage type of circuit. It has no capability of storing excess energy on the voltage peaks and inserting this energy during the period of voltage decline. It must, therefore, be preceded by a filter section capable of maintaining the minimum voltage "valleys" at 1 to 2 volts higher than the D. C. voltage (E_{dc}, *Fig. 28.1*) required across the output load at maximum current demand. The ripple filtering effect of the transistor ripple clipper is approximately that which would be realized if, in a conventional filter circuit, C_F (*Fig. 28.1*) were replaced by a capacitance equal to C_1 multiplied by the current gain (B) of the transistor.

The ripple clipper will operate most efficiently when the transistor is operated close to saturation. This means that the minimum voltage drop across the transistor is, perhaps, 1 to 2 volts for the maximum load current expected.

The importance of a good understanding of the energy dynamics involved may be illustrated by the following example. Let us suppose that it is desired to remove a ripple of 3 volts peak to peak from a nominally filtered 28 VDC-15-ampere supply. The power supply uses a full wave bridge rectifier, and an L or π filter.

The ripple voltage will be approximately a saw tooth so that the average ripple voltage will be ½ the peak to peak value, about 1½ volts. Let us assume that the biasing circuit is such that the transistor is operated near saturation and, therefore, has a minimum voltage drop across it of 1 volt.

The energy dissipated in the transistor then would be equal to the product of the load current and the sum of the average ripple voltage and the minimum drop across the transistor.

$$P = 15\ (1.5 + 1) = 37.5 \text{ watts}$$

With a maximum thermal resistance (Θ) of .7°C/watt (2N575) and a maximum allowable junction temperature of 95°C, the mounting stud temperature cannot be allowed to rise above:

$$T_{stud\ max} = T_{J\ max} - P\Theta$$
$$= 95°C - (37.5 \times .7) = 69°C$$

If the ambient temperature is 25°C, the chassis must have a maximum thermal resistance to the ambient of approximately 1.2 degrees per watt (i.e. (69-25)°C/37.5 watts). This would require, if convection in still air were the only means of cooling, a minimum of 250 square inches of surface area for the heat dissipator.

In the example above, if the transistor were not operated as close to saturation and had three volts instead of 1 volt of minimum drop across it, the power dissipated in the transistor would be:

$$P = 15\ (1.5 + 3) = 67.5 \text{ watts}$$

and the maximum allowable stud temperature would be:

$$T_{stud\ max} = 95°C - (67.5 \times .7 = 47.5°C$$

At the 25°C ambient, the maximum allowable thermal resistance of the chassis to ambient would have to be (47.5 — 25)°C/67.5 watts or .33°C/watt. This would call for a dissipator surface area of about 1,500 square inches for convection cooling. Of course, these figures can be radically reduced through use of forced air cooling.

It is possible to use these ripple clipper circuits to remove ripple from voltages in excess of the voltage ratings of the transistor under certain conditions. Under optimum steady state conditions, the transistor will see a maximum collector-to-emitter voltage of only the peak-to-peak ripple of the input voltage plus the minimum voltage of 1 to 2 volts. However, the supply voltage must be applied gradually to allow the condensers time to charge so that the transistor is not subjected to an instantaneous voltage in excess of its rating. If the output should become shorted, the full supply voltage will appear ocross the transistor and it will be destroyed if the heat dissipation capabilities of the transistor are exceeded or if the applied voltage exceeds the transistor $\alpha = 1$ voltage rating.

[Circle 149 on Reader Service Card]

APPLICATION ENGINEERING DIGEST NO. 29

2 Stage Compensated Transistor Preamplifier; Transitron Electronic Corp., Wakefield, Mass.

This transistor amplifier is designated for use in circuits requiring a relatively constant circuit current gain, B, with considerable variation of individual transistor parameters. It is designed to be driven from a high impedance source ($R_g \geq$ 20K).

The circuit is very stable and shows no tendency toward oscillations. The frequency response linearity at low frequencies is determined only by the coupling capacitors since the basic amplifier is flat down to D.C.

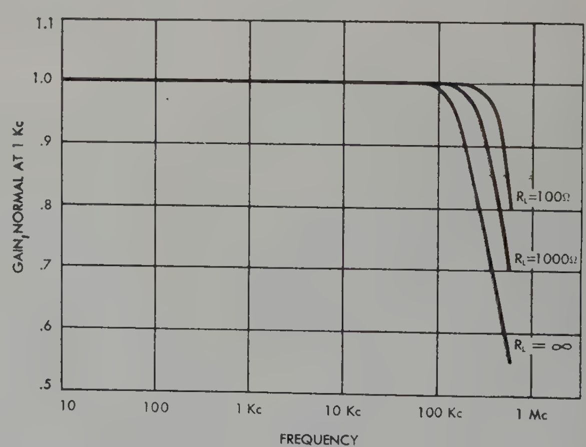
Since the current gain of the amplifier without the degeneration is much higher than the gain with feedback, the current gain is independent of the transistors and is equal to the ratio of R_F divided by the total dynamic resistance in the emitter lead of T_2. (In this case, 270 + 40 = 310 ohms.) Therefore the circuit current gain may be varied by changing either R_F or R_E.

In the circuit above, the circuit beta will be 100 ± 5 with transistors having individual betas of 30 or more.

The stabistor S320G is used to compensate for the variation of V_{BE} of T_1 with temperature. The stabistor SG22 is to protect transistor T_1 from an excess negative voltage applied to the input.

CHARACTERISTICS

Current Gain (R_L = 0, f = 1 Kc)	100 ± 5
Input resistance (10 cps to 10 Kc)	500 Ω typical
Output resistance	2000 Ω
frequency response	See curve
Maximum voltage output (R_L = ∞)	1.2 V rms
Maximum Current output (R_L = 0)	0.6 mAac
DC Stabilization (E_o/I_{co})	0.2 V/μa
Maximum undistorted power output	0.5 mw
Power drain	8 mw
Output Noise voltage (R_L = ∞, R_g = ∞, f = 5cps to 400 Kc)	200 μV
Equivalent input noise current (R_L = ∞, R_g = ∞, f = 5cps to 400 Kc)	1 mμA
Ambient temperature range	−65°C to +100°C
Temperature Stabilization (Eo/T)	2 mV/°C



[Circle 150 on Reader Service Card]

SEMICONDUCTOR & SOLID-STATE BIBLIOGRAPHY

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Negative and Oscillatory Longi-udinal Magneto-resistance	Canadian J1 Physics July 1959	Report on the result of numerical calculations of the longitudinal magnetoresistance of semiconductors and semimetals.	R. Barrie
Transistorized 20-Channel Car-ier Telegraph Terminal	Communications and Electronics AIEE July 1959	Paper describes physical and circuit description, the latter including the transmitter and receiver.	T. M. Grybowski W. G. Vieth
emotely Controlled Electrolumi-escent Totaling Display	Communications and Electronics AIEE July 1959	Device dscribed uses an electroluminescent phosphor to form a truly planar numerical indicator.	R. C. Lyman C. I. Jones A. Leger
lectrical Protection for Tran-istorized Equipment	Communications and Electronics AIEE July 1959	Source and nature of foreign potentials hazardous to dependable operation of communication equipment; protective measures employed.	D. W. Bodle J. B. Hays, Jr.
ransistorized Control Provides park-Free Switching	Elecl Des News July 1959	Circuit diagram and operation described.	
arge Signal Transient Behavior f Transistor Pulse Amplifiers	Electronic Design July 8 1959	Can be determined with a few handy equations which are presented. Practical example solved.	R. C. Dorf
nderstanding Transistor Voltage reakdown	Electronic Design July 22 1959	How voltage breakdown takes place, its various forms, and its dependence on external circuit characteristics.	H. E. Schauwecker
leasuring Transistor Parameters vith Wayne Kerr RF Bridges	Electronic Design July 22 1959	These bridges are capable of measuring either 2-terminal (driving point) admittances, or transfer admittances of a 3-terminal network over a wide frequency range.	R. M. Scarlett
lew Approach to Transistor Bias	Electronic Design July 22 1959	Straightforward though unconventional approach takes into account variations in β. Simplifying assumptions are made.	J. P. White
ransistor Circuits for a 1-MC igital Computer	Electronic Eng July 1959	The requirements of amplifiers used for pulse regeneration are considered; suitable blocking oscillators and regenerative amplifiers are described.	I. Krajewski
ransistor Inverters and Rectifier ilter Units	Electronic Eng July 1959	Following an elementary discussion of transistor inverters, details are given of two practical designs of units operating from a 12-volt supply.	F. Butler
lodern Design Techniques for ransistor Equipment	Electronic Equip Eng July 1959	Commercial methods of solving heat dissipation problems when using power transistors are presented.	
udio Impedance Meter	Electronic Equip Eng July 1959	Description of an instrument that measures resistance and reactance at audio frequencies.	R. L. Weber
esigning Degenerative Transistor mplifiers	Electronic Equip Eng July 1959	Design equations are developed showing input impedance and power gain for a base input amplifier having a shunt resistor from base to emitter.	W. D. Roehr
ransistor Regulated Power Sup-ly	Electronic Equip Eng July 1959	Design details of unit that provides sufficient power and adequate regulation for small signal applications, or for powering receivers.	J. Carter, Jr.
issipating Heat from Transistors	Electronic Equip Eng July 1959	Heat dissipators described give increased life and more efficient operation of a semi-conductor device.	P. J. Burke
hermoelectricity—State of the rt	Electronic Industries July 1959	Elementary principles discussed. The extent to which industrial and governmental agencies have progressed in the production of materials and devices.	C. Celent
esigning Transistorized Video mplifiers	Electronic Industries July 1959	Step-by-step procedures given. Two types of 3-transistor circuits are described.	R. G. Salaman
nalyzing Networks with the Y-latrix	Electronic Industries July 1959	Examples given in this article are given for 3-terminal networks; methods are extendable to networks with more than three terminals.	W. J. D. Stuart
ransistor Current Gain	Elecnc Rad Eng (Br) July 1959	Apparatus for a twin-channel method of measuring complex values of a at frequencies between 1-210 *mc*, and for a single-channel null method of frequencies up to 25 *mc* are described.	R. W. Smith F. J. Hyde
lectroluminescent Panels for utomatic Displays	Electronics July 10 1959	Description of plate construction, system operation, decoding, and receiver sections are given.	R. C. Lyman C. I. Jones
hotoelectric Scanners Control us Traffic	Electronics July 10 1959	Scanning units at several checkpoints detect the passage of a bus, and relay the information to a control center.	T. S. Pick A. Readman
lew Frontiers for Semiconductors	Electronics July 17 1959	Examination of the periodic table of elements shows that elements and compounds, other than those well known, give promise of useful semiconductors.	C. A. Escoffery
mplifiers for Strain Gages and hermocouples	Electronics July 24 1959	Positive and negative feedback to a bridge-type transformer-coupled input circuit are used to attain high-impedance differential input in a d-c to 25 *kc* amplifier.	R. S. Burwen
requency Control of Magnetic lultivibrators	Electronics July 24 1959	Magnet-coupled transistorized multivibrator circuits permit wide range, step-by-step continuous control of output frequency.	W. A. Geyger
ow to Construct a Miniature -M Transmitter	Electronics July 31 1959	Portable transistor transmitter that is easy to build with standard commercial components at low cost; range is 200 feet.	D. E. Thomas J. M. Klein
witching Circuits for Missile ount-Downs	Electronics July 31 1959	Transistorized level-sensitive switch uses non-linear negative feedback to provide stable operation over wide temperature ranges.	D. W. Boensel
ransistorizing Electronic Equip-nent	Electronics July 31 1959	Availability, selection, and state-of-the-art limitations of transistors and other semi-conductors are discussed.	R. K. Jurgen
ome Properties of Experimental 000-MC Transistors	IBM J1 Res & Dev July 1959	Devices described, and measurements of their parameters are discussed. An oscillator in which the transistors operated up to 1550 *mc* is described.	R. F. Rutz D. F. Singer
uby as a Maser Material	J1 Applied Physics July 1959	The reasons for the initial choice of ruby as a maser material are outlined and some measurements are reported.	C. Kikuchi J. Lambe R. W. Terhune G. Makhov

SEMICONDUCTOR & SOLID-STATE BIBLIOGRAPHY

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Method for Calculating Simultaneous Resonance Conditions in a Three-Level Ruby Maser	Jl Applied Physics July 1959	A method is described allowing direct calculation of external field H, and crystal orientation θ.	M. A. Garstens
Diffusion of Copper in Cadmium Sulfide Crystals	Jl Applied Physics July 1959	Copper was diffused in cadmium sulfide crystals to determine diffusion coefficients using the radio-active tracer sectioning technique.	R. L. Clarke
X-Ray Method for the Differentiation of (111) Surfaces in A^{III} B^{V} Semiconducting Compounds	Jl Applied Physics July 1959	X-Ray measurements of a series of (111) reflections from opposite sides of an InAs single crystal have been made and related to the etching characteristics of these surfaces.	E. P. Warekois P. H. Metzger
Dynamic Properties of the Polarizability in $BaTiO_3$ Crystal	Jl Applied Physics July 1959	The second harmonic distortion by a $BaTiO_3$ crystal of a small h-f sinusoidal elective field superimposed on an l-f switching field is studied by the filter method.	K. Husimi
Transient Response of Grain Boundaries and its Application for a Novel Light Sensor	Jl Applied Physics July 1959	A photosensor based on semiconductor principles is described, and preliminary experimental results are reported.	R. K. Mueller
Microplasma Fluctuations in Silicon	Jl Applied Physics July 1959	The electrical properties of a fluctuating bistable microplasma are specified by three parameters which, in general, are functions of voltage.	K. S. Champlin
$InAs_{1-x}$ P_x as a Thermoelectric Material	Jl Applied Physics July 1959	Measurements of electrical conductivity, thermal conductivity, and Seebeck co-efficient have been made at high temperature, with K varying from 0 to 0.4.	R. Bowers J. E. Bauerle A. J. Cornish
Microwave Techniques in Measurement of Lifetime in Germanium	Jl Applied Physics July 1959	New techniques are proposed for the measurement of lifetime in semiconductors by utilizing the absorption of microwave power by charge carriers.	A. J. Ramsa H. Jacobs F. A. Brand
Ferroelectric Properties of Colemanite	Jl Applied Physics July 1959	The ferroelectric properties of calcium borate mineral colemanite are investigated in the ferroelectric and paraelectric temperature regions.	H. H. Wieder
Polarization Reversal by Sideways Expansion of Domains in Ferroelectric Triglycine Sulfate	Jl Applied Physics July 1959	At fields in the range 30-35V cm^{-1}, polarization reversal is accomplished by the formation and sideways expansion of a relatively few domains.	A. G. Chynoweth J. L. Abel
Contribution to a General Theory of Thermocouples	Jl Applied Physics July 1959	Application of thermodynamic processes to a thermocouple leads to two nonlinear differential equations describing the stationary distribution of temperature and electrical potential.	A. H. Boerdijk
Electrochemistry of the Semiconductor-Electrolyte Electrode. I—The Electrical Double Layer	Jl Chemical Phys July 1959	Equilibrium potential distribution between the bulk of a solid semiconductor and the bulk of an electrolyte solution with which it is in contact, when the semiconductor is one electrode of an electrochemical cell.	M. Green
Photoconduction and Cis-Trans Isomerism in β-Carotene	Jl Chemical Phys July 1959	A discussion is given of some theoretical and experimental aspects of photoconductivity in β-carotene a C_{40} carotenoid.	B. Rosenberg
Uniform Resistivity *p*-Type Silicon by Zone Leveling	Jl Electrochem Soc July 1959	Silicon single crystals nominally 1 cm in diameter and 16 cm long have been grown with aluminum doping in a floating zone apparatus.	E. D. Kolb M. Tanenbaum
On The Jet Etching of *n*-Type Si	Jl Electrochem Soc July 1959	The rate is controlled by two factors: supply of injected minority carriers and rate of dissolution of the SiO_2 film.	P. F. Schmidt D. A. Keiper
A Silicon *p-n-p-n* Power Triode	Jl Elecncs & Cont (Br) April 1959	Simplified theory of *p-n-p-n* switching is presented; observations are made on a developmental silicon *p-n-p-n* power triode. Description of fabrication.	Y. Kawana T. Misawa
Measurement of the High-Frequency Base Resistance and Collector Capacitance of Drift Transistors	Jl Elecncs & Cont (Br) April 1959	A biased thermistor issued to provide a variable *r-f* resistance for the measurement of r_{bb}' and C_c. The effect of stray emitter-collector capacitance is analyzed.	F. J. Hyde T. E. Price
A Reliable Method for the Production of High Impurity Indium Antimonide	Jl Elecncs & Cont (Br) May 1959	Details of the apparatus and method are given, and the factors limiting the purity are considered.	K. F. Hulme
Effects of Heat Treatment on the Electrical Properties of Silicon	Jl Phys Soc Japan July 1959	Experimental studies have been made of the processes in which the changes of carrier concentrations and minority carrier lifetime are introduced into silicon by heat treatment at the temperature range 400-1200° C.	Y. Matukura
On the Non-Isothermal Diffusion Theory of Rectifiers	Jl Phys Soc Japan July 1959	This theory has been derived using the non-isothermal diffusion equation deduced from the formal theory of conduction.	T. Numata
The Design of a Standard Block for a Digital Computing System	Mullard Tech Comm April 1959	A complete design procedure is given for the Mullard OC42 at a clock frequency of 750 kc.	R. J. Miles
A 4-Watt 500 KC Transistor Transmitter	Mullard Tech Comm May 1959	The transmitter is designed for operation in the International Marine Frequency Band; may be used in a variety of portable requirements.	J. R. Nowicki
Photo-Resistors Made of Compressed and Sintered Cadmium Sulphide	Philips Tech Review July 1959	Article describes how photo-resistors can be produced on an industrial scale and discusses some of their many possible applications.	N. A. de Gier W. van Gool J. G. van Santen
Recombination Properties of Nickel in Germanium	Physical Review July 1 1959	Studies have shown that the recombination process must be interpreted in terms of a multilevel model, with three charge states assigned to nickel.	G. K. Wertheim
Studies of the Semiconducting Properties of the Compound CsAu	Physical Review July 1 1959	Verification of CsAu as a semiconductor, investigation of its semiconducting properties, indication of possible band models, and suggested nature of the chemical bonding.	W. E. Spicer A. H. Sommer J. G. White
Piezoresistance of *n*-Type Germanium	Physical Review July 15 1959	The change of electrical resistance in uniaxial tension has been measured over the range 6° K to 300° K.	H. Fritzsche
Recombination Processes in *p*-Type Indium Antimonide	Physical Review July 15 1959	PEM and PC lifetimes have been measured from 77° to 300° K in InSb of net acceptor concentration ranging from 10^{15} to 10^{18} cm^{-3}.	R. N. Zitter A. J. Strauss A. E. Attard

SEMICONDUCTOR & SOLID-STATE BIBLIOGRAPHY

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Electron Damage Thresholds in InSb	Physical Review July 15 1959	Measurement of carrier removal rate and isochronal recovery in electron-irradiated InSb indicate that displacements are produced at electron energies as low as 240 kev.	F. H. Eisen P. W. Bechel
Tunnel Diodes as Highway Frequency Devices	Proceedings IRE July 1959	Experimental and theoretical results are given which show great promise for operation in the frequencies of the order of kilomegacycles.	H. S. Sommers, Jr.
The Cryosar—A New Low-Temperature Computer Component	Proceedings IRE July 1959	The cryosar is a high-speed 2-terminal semi-conductor device whose operation, at liquid helium temperature (4.2° K) is based on impact ionization of impurities in germanium.	A. L. McWhorter R. H. Rediker
Analog Computer Measurements on Saturation Currents, Admittances and Transfer Efficiencies of Semiconductor Junction Diodes and Transistors	Proceedings IRE July 1959	Solutions of the diffusion equation assuming a 3-dimensional structure are performed with a computer. Comparisons are made, and some unexpected features are observed.	A. H. Frei M. J. O. Strutt
An Investigation of the Dependence of the Current Gain of a Plane-Alloy-Junction Transistor on Emitter Current and Frequency	Proc Inst EE (Br) July 1959	The complex internal current gain, of a diffusion-type germanium transistor has been derived from measurements of the external current gain, a_d, at frequencies up to 20 *mc*, and for emitter current between 15 μs and 3 *ma*.	F. J. Hyde
An Investigation of the Current Gain of a Drift Transistor at Frequencies up to 105 MC	Proc Inst EE (Br) July 1959	The complex internal short-circuit current gain, a_d, of a type 2N247, has been determined from measurements of the external short-circuit current gain.	F. J. Hyde
High Frequency Power Gain of the Drift Transistor	Proc Inst EE (Br) July 1959	Approximate expressions are derived for the critical frequency above which the ideal transistor is unconditionally stable, and the resulting maximum available gain for the CE configuration.	
The Selective Photoelectric Effect	Proc Phys Soc (Br)	The spectral selective photoelectric effect in alkali metals is considered as a local field, phenomenon taking place in a colloidal surface structure.	W. T. Doyle
Properties of *p*-Type Indium Antimonide. II. Photoelectric Properties and Carrier Lifetime	Proc Phys Soc (Br)	Photoconductive and photoelectromagnetic effects were studied on *p*-type specimen of InSb with impurity concentrations varying from 10^{15} to 2×10^{17} cm $^{-3}$.	C. Hilsum
The Fine Structure of Photoconductivity Spectral Response Curves for Cadmium Sulfide Crystals	Sov Phys Sol State Vol 1 No 3 1959	More than sixty specimens were investigated at T = 77.3° K. Techniques of measurements and results are described.	E. F. Gross B. V. Novikov
An Investigation of Infrared Absorption by Minority Carriers in Germanium	Sov Phys Sol State Vol 1 No 3 1959	Absorption spectra due to hole injection in germanium were investigated over the wavelength region 2 to 13μ at room temperature and at T = 105° K.	Yu I. Ukhanov
The Specific Heats of a Number of Semiconductors	Sov Phys Sol State Vol 1 No 3 1959	Specific heat or Debye temperature Θ_D is frequently needed to interpret electrical properties and heat conductivity. Many semiconductors are investigated for a wide range of temperatures.	P. V. Gul'tyaev A. V. Petrov
Exposure of Dislocations in Germanium and Silicon by Etching	Sov Phys Sol State Vol 1 No 3 1959	Detailed description of successful techniques used by the authors.	A. D. Trakhtenberg S. M. Fainshtein
Long-Period Contact Potential and Conductivity Variations in Germanium Due to the Action of Light and of A Perpendicular Electric Field	Sov Phys Sol State Vol 1 No 3 1959	Various proposed models of the surface are investigated, and it is shown that only the Kingston and McWhorter models give satisfactory agreement between the variation of the contact potential with time and corresponding data.	M. S. Kosman I. I. Abkevich
On the Problem of Dependence of the Electrical Conductivity of Polycrystalline Cadmium Selenide on the Electric Field Intensity	Sov Phys Sol State Vol 1 No 3 1959	Dependence of the electrical conductivity of polycrystalline cadmium selenide on the electric field intensity up to 10^4 V/cm was studied.	I. M. Yashukova
Electrical Properties of the Intermetallic Compound CdSb with Indium Impurity	Sov Phys Sol State Vol 1 No 3 1959	The present paper reports studies of the temperature dependence of the electrical conductivity, the Hall effect, and the thermo-electric power of CdSb samples with indium impurity.	I. M. Pilat V. D. Iskra V. B. Shuman
Preparation of Mixed CdS•CdSe Monocrystals from the Vapor Phase and Some of Their Properties	Sov Phys Sol State Vol 1 No 3 1959	The work described in this paper is a continuation of earlier investigations on the technique of preparation of CdS and CdSe monocrystals from the vapor phase.	N. I. Vitrikhovskii I. B. Mizetskaya
Production of High-Impurity Single Crystals of InSb by Zone Melting	Sov Phys Sol State Vol 1 No 3 1959	The purpose of the present work was to produce ultra pure single crystals of InSb by zone melting and to increase the yield of material.	K. I. Vinogradova V. V. Galavanov D. N. Nasledov L. I. Solov'eva
Symmetry of Energy Bands in Crystals of Wurtzite Type	Sov Phys Sol State Vol 1 No 3 1959	Symmetry of bands disregarding spin-orbit interaction. A theoretical analysis is made of the structure of the energy bands in lattices of the wurtzite type in the absence of spin-orbit coupling.	E. I. Rashba
The Problem of the Scattering of Charge Carriers at Impurity Centers	Sov Phys Sol State Vol 1 No 3 1959	Expressions are derived for the relaxation time and the mobility of the carriers in the case of repelling and attracting potentials.	Yu. V. Gulyaev
Regarding the Nature of the Surface Film of the L-Cathode	Sov Phys Sol State Vol 1 No 3 1959	An attempt is made to verify the presence of the hypothetical semiconductor film present between the tungsten sponge and the surface of the monoatomic film of barium.	D. G. Bulyginskii
Transistor Module Testing	Sylvania Tech July 1959	A new method of testing circuits that are packaged into small modules and are used in high-speed digital computers is described.	J. E. Monahan
Circuit Designs for a General Purpose Counter	Sylvania Tech July 1959	Circuits discussed are the inverter, emitter-follower, flip-flop, register and pulse driver, bus driver, clock generator and accumulator carry chain.	T. E. Baker, Jr. E. U. Cobler M. I. Crystal J. E. Monahan
Improvements in Synchronous Motor Control	Westinghouse Engr July 1959	The transistor can now replace the conventional magnetic relay and be used as the basic building block of control systems.	D. J. MacGregor R. M. Hayford

CHARACTERISTICS CHARTS OF NEW DIODES and RECTIFIERS

ANNOUNCED BETWEEN AUG. 1, 1959 and SEPT. 30, 1959 ONLY. This is a partial listing and will be continued from the previous issue

MANUFACTURERS

AEG—	Allgemeine Elekticitats-Gesellschaft
AEI—	Associated Electrical Industries, Ltd.
AMP—	Amperex Electronic Corp.
AUD—	Audio Devices, Inc.
BEN—	Bendix Aviation Corp.
BER—	Berkshire Labs
BOG—	Bogue Electric Mfg. Co.
BOM—	Bomac Labs
BRA—	Bradley Labs
CBS—	CBS Electronics
CDC—	Continental Device Corp.
COL—	Columbus Electronics Corp.
CTP—	Clevite Transistor Products, Inc.
CSF—	Compagnie Generale de T.S.F.
EEVB—	English Electric Valve Co., Ltd.
ERI—	Erie Resistor Corp.
FAN—	Fansteel Metallurgical Corp.
FERB—	Ferranti Ltd.
GAH—	Gahagan, Inc.
GECB—	General Electric Co., Ltd.
GE—	General Electric Company, Semiconductor Div.
GIC—	General Instrument Corp.
GTC—	General Transistor Corp.
HAFO—	Institutet for Halvedarforskning
HSD—	Hoffman Semiconductor Division
HUG—	Hughes Products Division
INRC—	International Rectifier Corp.
IRC—	International Resistance Co.
ITT—	International Tel. & Tel. Corp.
KEM—	Kemtron Electron Products, Inc.
LCTF—	Laboratoire Central de Telecommunications
MAL—	P. R. Mallory & Co., Inc.
MIC—	Microwave Associates, Inc.
MOT—	Motorola, Inc.
MUL—	Mullard, Ltd.
NAE—	North American Electronics
NPC—	Nucleonic Products Co., Inc.
OHM—	Ohmite Manufacturing Co.
PHI—	Philco Corp. Lansdale Tube Company
PSI—	Pacific Semiconductors, Inc.
QSC—	Qutronic Semiconductor Corp.
RAY—	Raytheon Company
RCA—	Radio Corporation of America, Semiconductor Div.
RHE—	Rheem Semiconductor Corp.
SAR—	Sarkes Tarzian, Inc., Rectifier Division
SCN—	Semicon, Inc.
SEM—	Semi-Elements Inc.
SIE—	Siemens & Halske Aktiengesellschaft
SIL—	Silicon Transistor Corp.
SSD—	Sperry Semiconductor Division
SSP—	Solid State Products, Inc.
STC—	Shockley Transistor Corp.
STCB—	Standard Telephone & Cables, Ltd.
SYL—	Sylvania Electric Products, Inc.
SYN—	Syntron Co.
TEX—	Texas Research Assoc.
TFKG—	Telefunken, Ltd.
THE—	Thermosen, Inc.
TI—	Texas Instruments, Inc.
TKD—	Tekade, Nurnberg, Germany
TOK—	Tokyo Tsushin Kogyo, Ltd.
TRA—	Transitron Electronic Corp.
TUN—	Tung-Sol Electric, Inc.
TSC—	Trans-Sil Corp.
USD—	United States Dynamics Corp.
USS—	U. S. Semiconductor Products, Inc.
VIC—	Vickers Inc.
WEC—	Western Electric Co.
WEST—	Westinghouse Electric Corp.

NEW DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV	MAX. CONT. WORK. VOLT.	Min. Forward Current @ 25°C		MAX. D.C. OUTPUT CURRENT[4]	@ T (°C)	MAX. FULL LOAD VOLT. DROP[4]	Max. Rev. Current			MFR. (See code at start of charts)
					I_f	@ E_f				I_b	@ E_b	@ T	
			(volts)	(volts)	(mA)	(volts)	(amps)		(volts)	(uA)	(volts)	(°C)	
BR500	2	Si		1100			.50	150	1.8	100	1100	150	BRA
BR600	2	Si		1200			.50	150	1.8	100	1200	150	BRA
BR700	2	Si		1300			.50	150	1.8	100	1300	150	BRA
BR800	2	Si		1400			.50	150	1.8	100	1400	150	BRA
BR900	2	Si		1500			.50	150	1.8	100	1500	150	BRA
BR1000	2	Si		1600			.50	150	1.8	100	1600	150	BRA
BY301	2	Si		50			2.5	150	1.2	500	50	150	BRA
BY302	2	Si		100			2.5	150	1.2	500	100	150	BRA
BY303	2	Si		200			2.5	150	1.2	500	200	150	BRA
BY304	2	Si		300			2.5	150	1.2	500	300	150	BRA
BY305	2	Si		400			2.5	150	1.2	500	400	150	BRA
BY306	2	Si		500			2.5	150	1.2	500	500	150	BRA
BY307	2	Si		600			2.5	150	1.2	500	600	150	BRA
BY308	2	Si		700			2.5	150	1.2	500	700	150	BRA
BY309	2	Si		800			2.5	150	1.2	500	800	150	BRA
BY311	2	Si		50			2.5	150	1.0	100	50	150	BRA
BY312	2	Si		100			2.5	150	1.0	100	100	150	BRA
BY313	2	Si		200			2.5	150	1.0	100	200	150	BRA
BY314	2	Si		300			2.5	150	1.0	100	300	150	BRA
BY315	2	Si		400			2.5	150	1.0	100	400	150	BRA
BY316	2	Si		500			2.5	150	1.0	100	500	150	BRA
BY317	2	Si		600			2.5	150	1.0	100	600	150	BRA
BY318	2	Si		700			2.5	150	1.0	100	700	150	BRA
BY319	2	Si		800			2.5	150	1.0	100	800	150	BRA
BY321	2	Si		50			2.5	150	1.5	1000	50	150	BRA
BY322	2	Si		100			2.5	150	1.5	1000	100	150	BRA
BY323	2	Si		200			2.5	150	1.5	1000	200	150	BRA
BY324	2	Si		300			2.5	150	1.5	1000	300	150	BRA
BY325	2	Si		400			2.5	150	1.5	1000	400	150	BRA
BY326	2	Si		500			2.5	150	1.5	1000	500	150	BRA
BY327	2	Si		600			2.5	150	1.5	1000	600	150	BRA
BY328	2	Si		700			2.5	150	1.5	1000	700	150	BRA
BY329	2	Si		800			2.5	150	1.5	1000	800	150	BRA
BY408	2	Si		700			6.0	150	1.2	500	700	150	BRA
BY409	2	Si		800			6.0	150	1.2	500	800	150	BRA
BY418	2	Si		700			6.0	150	1.0	100	700	150	BRA
BY419	2	Si		800			6.0	150	1.0	100	800	150	BRA
BY428	2	Si		700			6.0	150	1.5	1000	700	150	BRA
BY429	2	Si		800			6.0	150	1.5	1000	800	150	BRA
BY508	2	Si		700			12	150	1.2	1000	700	150	BRA
BY509	2	Si		800			12	150	1.2	1000	800	150	BRA
BY518	2	Si		700			12	150	1.0	200	700	150	BRA
BY519	2	Si		800			12	150	1.0	200	800	150	BRA
BY528	2	Si		700			12	150	1.5	2000	700	150	BRA
BY529	2	Si		800			12	150	1.5	2000	800	150	BRA

TYPE NO.	USE (See Code Below)	MAT	PIV	MAX. CONT. WORK. VOLT.	Min. Forward Current @ 25°C		MAX. D.C. OUTPUT CURRENT[4]	@ T (°C)	MAX. FULL LOAD VOLT. DROP[4]	Max. Rev. Current			MFR. (See code at start of charts)
					I_f	@ E_f				I_b	@ E_b	@ T	
			(volts)	(volts)	(mA)	(volts)	(amps)		(volts)	(uA)	(volts)	(°C)	
BY3001	2	Si		900			2.5	150	1.2	500	900	150	BRA
BY3002	2	Si		1000			2.5	150	1.2	500	1000	150	BRA
BY3101	2	Si		900			2.5	150	1.0	100	900	150	BRA
BY3102	2	Si		1000			2.5	150	1.0	100	1000	150	BRA
BY3201	2	Si		900			2.5	150	1.5	1000	900	150	BRA
BY3202	2	Si		1000			2.5	150	1.5	1000	1000	150	BRA
BY4001	2	Si		900			6.0	150	1.2	500	900	150	BRA
BY4002	2	Si		1000			6.0	150	1.2	500	1000	150	BRA
BY4101	2	Si		900			6.0	150	1.0	100	900	150	BRA
BY4102	2	Si		1000			6.0	150	1.0	100	1000	150	BRA
BY4201	2	Si		900			6.0	150	1.5	1000	900	150	BRA
BY4202	2	Si		1000			6.0	150	1.5	1000	1000	150	BRA
BY5001	2	Si		900			12	150	1.2	1000	900	150	BRA
BY5002	2	Si		1000			12	150	1.2	1000	1000	150	BRA
BY5101	2	Si		900			12	150	1.0	200	900	150	BRA
BY5102	2	Si		1000			12	150	1.0	200	1000	150	BRA
BY5201	2	Si		900			12	150	1.5	2000	900	150	BRA
BY5202	2	Si		1000			12	150	1.5	2000	1000	150	BRA
FST1/4	2	Si	400	400			.50	50	1.1				STCB(6)
GEX542	2	Ge	160	160			6.0	55		15ma	160	70	GECB
RS50AF	2	Si	50	50			5.0	100	1.3	100(4)	50	25	STCB(6)
RS51AF	2	Si	100	100			5.0	100	1.3	100(4)	100	25	STCB(6)
RS52AF	2	Si	150	150			5.0	100	1.3	100(4)	150	25	STCB(6)
RS53AF	2	Si	200	200			5.0	100	1.3	100(4)	200	25	STCB(6)
RS54AF	2	Si	300	300			5.0	100	1.3	100(4)	300	25	STCB(6)
RS55AF	2	Si	400	400			5.0	100	1.3	100(4)	400	25	STCB(6)
RS80AF	2	Si	50	50			60	100	1.2	50ma(4)	50	25	STCB(6)
RS81AF	2	Si	100	100			60	100	1.2	50ma(4)	100	25	STCB(6)
RS82AF	2	Si	150	150			60	100	1.2	50ma(4)	150	25	STCB(6)
RS83AF	2	Si	200	200			60	100	1.2	50ma(4)	200	25	STCB(6)
RS84AF	2	Si	300	300			60	100	1.2	50ma(4)	300	25	STCB(6)
S262	1	Si	30	15	3.0	1.0	.03			150	15	55	AMP
S11-200	1	Si	200	200			1.0	135C	.75	200	200	25	HAFO
S11-400	1	Si	400	400			1.0	135C	.75	200	400	25	HAFO
S11-600	1	Si	600	600			1.0	135C	.75	200	600	25	HAFO

NOTATIONS

Under Use

1. General Purpose
2. Power Rectifier
3. Magnetic Amplifier

Ø Insulated Base

5. Controlled Rectifier
6. Dual Rectifier

△ Direct Tube Replacement

Other

4. For half wave resistive load average over 1 cycle

Under Reverse Current

Ø Dynamic

Under Mfr.

6. Available in stack form from that manufacturer

Following any temperature reading these symbols apply

A — Ambient
C — Case
J — Junction
S — Storage
△ —Inlet Temperature of Coolant

Type No.

† —Revised Data

Manufacturers should be contacted for value and test condition for surge current and maximum peak recurrent current

Under E_f

Ø - at 125°C

CHARACTERISTICS CHART of MISCELLANEOUS DIODE TYPES

TYPE NO.	CLASSIFI-CATION	DESCRIPTION	MFR.
1N76A	1,2	Video Detector	SYL
1N830A	2	UHF Micro-Min Diode	SYL
1N1838	2	Low Flicker Noise Doppler Mixer Diode	PHI
1N2510	1,2	X-Band Coaxial Diode	SYL
1N2510R	1,2	X-Band Coaxial Diode	SYL
MA437/1N2771	1,2	VHF/UHF Power Monitor Diode	MIC
MA439	1,2	X Band Controlled Voltage Detector	MIC
MA440	1,2	1600 Mc- Coaxial Mixer, Lc- 5.7db max; Noise Ratio- 1.3max; Overall Noise- 7.8dbmax.	MIC
MA440R	1,2	Reversed Polarity Version of MA440	MIC
MA-H	1,3	Parametric Amplifier Varactor Diode for 144Mc - 440 Mc region	MIC
SCR961	8	PIV 25V.; Average I_f- 10A.	GECB
SCR962	8	PIV 50V.; Average I_f- 10A.	GECB
SCR963	8	PIV 100V.; Average I_f- 10A.	GECB
SCR964	8	PIV 150V.; Average I_f- 10A.	GECB
SCR965	8	PIV 200V.; Average I_f- 10A.	GECB

Notations Under Classification

1. Microwave diodes
2. Mixer or detector diodes
3. Varactor diodes
4. Photodiodes
5. Solar Cells
6. Harmonic Generator diodes
7. 4-Layer bistable diodes
8. Controlled rectifier

CHARACTERISTICS CHART of SILICON ZENER or AVALANCHE DIODES

TYPE NO.	Zener or Avalanche Voltage Range			Dynamic Impedance		MAX. DISS.	TEMP. CO-EF-FICIENT	MFR. (See code at start of chart)
	MIN. Eb1 (volts)	MAX. Eb2 (volts)	@ Iz (ma)	Z @ Iz (ohms)	(ma)	(mw)	%/°C	
1N1483	5.79	6.51	200	4.0	200	10W	.03	WEC
1N2765	6.46	7.14	7.5	20	7.5		.005	PSI
1N2765A	6.46	7.14	7.5	20	7.5		.0025	PSI
1N2766	12.92	14.28	7.5	40	7.5		.005	PSI
1N2766A	12.92	14.28	7.5	40	7.5		.0025	PSI
1N2767	19.38	21.42	7.5	60	7.5		.005	PSI
1N2767A	19.38	21.42	7.5	60	7.5		.0025	PSI
1N2768	25.84	28.56	7.5	80	7.5		.005	PSI
1N2768A	25.84	28.56	7.5	80	7.5		.0025	PSI
1N2769	32.3	35.7	7.5	100	7.5		.005	PSI
1N2769A	32.3	35.7	7.5	100	7.5		.0025	PSI
1N2770	38.78	42.84	7.5	120	7.5		.005	PSI
1N2770A	38.78	42.84	7.5	120	7.5		.0025	PSI
HPZ8.2Ø	7.70	8.65	500	1.0	500	35W	.040	USS
HPZ9.1Ø	8.60	9.60	500	1.0	500	35W	.050	USS
HPZ10 Ø	9.50	10.50	500	1.2	500	35W	.058	USS
HPZ11 Ø	10.4	11.6	440	1.3	440	35W	.059	USS
HPZ12 Ø	11.5	12.7	410	1.4	410	35W	.059	USS
HPZ13 Ø	12.6	14.0	390	1.5	390	35W	.060	USS
HPZ15 Ø	13.9	15.6	330	1.7	330	35W	.060	USS
HPZ16 Ø	15.4	17.1	310	1.8	310	35W	.061	USS
HPZ18 Ø	17.0	18.9	280	2.0	280	35W	.062	USS
HPZ20 Ø	18.8	20.8	250	2.0	250	35W	.063	USS
HPZ22 Ø	20.7	22.9	230	2.5	230	35W	.064	USS
HPZ24 Ø	22.8	25.2	210	3.0	210	35W	.065	USS
HPZ27 Ø	25.1	28.1	190	3.5	190	35W	.066	USS
HPZ30 Ø	28.0	31.0	170	4.0	170	35W	.067	USS
HPZ33 Ø	30.9	34.2	150	4.5	150	35W	.068	USS
HPZ36 Ø	34.2	37.8	140	5.0	140	35W	.069	USS
HPZ39 Ø	37.0	40.9	130	5.5	130	35W	.070	USS
HPZ43 Ø	40.8	45.0	120	6.0	120	35W	.071	USS
HPZ47 Ø	44.0	50.0	110	6.5	110	35W	.072	USS
HPZ51 Ø	48.0	54.0	100	7.0	100	35W	.074	USS
HPZ56 Ø	53.0	58.8	90	7.5	90	35W	.075	USS
HPZ62 Ø	58.7	64.8	80	8.0	80	35W	.077	USS
HPZ68 Ø	64.6	71.4	70	9.5	70	35W	.080	USS
HPZ75 Ø	71.0	78.0	65	11	65	35W	.083	USS
HPZ82 Ø	77.0	86.5	60	13	60	35W	.086	USS
HPZ91 Ø	86.0	96.0	55	18	55	35W	.090	USS
HPZ100Ø	95.0	105	50	20	50	35W	.093	USS
RS6	5.0	7.0	10	15	10			HSD
RT6	5.0	7.0	10	20	10			HSD
SZT1	4.95	6.05	5.0	30	5.0	300	.01 max	GECB
SZT2	4.95	6.05	5.0	30	5.0	300	.001max	GECB
Z2A33F	3.10	3.50	20	37	20	1000	.062	STCB
Z2A36F	3.40	3.80	20	35	20	1000	.056	STCB
Z2A39F	3.70	4.15	20	33	20	1000	.050	STCB
Z2A43F	4.05	4.50	20	31	20	1000	.045	STCB
Z2A47F	4.45	4.95	20	28	20	1000	.037	STCB
Z2A51F	4.85	5.40	20	26	20	1000	.017	STCB
Z2A56F	5.30	5.95	20	23	20	1000	.004	STCB
Z2A62F	5.85	6.55	20	19	20	1000	.031	STCB
Z2A68F	6.45	7.20	20	15	20	1000	.042	STCB
Z2A75F	7.10	7.90	20	15	20	1000	.050	STCB
Z2A82F	7.80	8.70	20	19	20	1000	.055	STCB
Z2A91F	8.60	9.60	20	23	20	1000	.060	STCB
Z2A100F	9.50	10.50	20	27	20	1000	.065	STCB
Z2A110F	10.40	11.50	20	32	20	1000	.070	STCB
Z2A120F	11.40	12.50	20	36	20	1000	.073	STCB
Z2A130F	12.40	14.00	20	43	20	1000	.078	STCB
Z2A150F	13.90	15.55	20	50	20	1000	.080	STCB

Under Type No.

Ø- Revised Spec.

CHARACTERISTICS CHART of SWITCHING DIODES

TYPE NO.	MAT	PIV (volts)	MAX. CONT. REV. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f (mA)	@ E_f (volts)	Reverse Impedance @ 25°C Z (K ohms)	VOLTAGE RANGE E_{b1} to E_{b2} (volts)	Recovery Characteristics TEST CONDITIONS Fwd. I_f (ma)	Rev. to E_b (volts)	$Z_{rec.}$ (K ohms)	@ time (t) (usec)	MFR. (See code at start of charts)
1N891	Si	60	50	50	1.0					80	.30	RHE
1N892	Si	120	100	50	1.0					80	.30	RHE
1N893	Si	240	200	50	1.0					80	.30	RHE
1N903	Si	40	40	10	1.0	40000min	up to 40	10	5.0	40000	.004	MIC
1N904	Si	30	30	10	1.0	30000min	up to 30	10	5.0	30000	.004	MIC
1N905	Si	20	20	10	1.1	20000min	up to 20	10	5.0	20000	.004	MIC
1N906	Si	20	20	10	1.0	20000min	up to 20	10	5.0	20000	.004	MIC
1N907	Si	30	30	10	1.0	30000min	up to 30	10	5.0	30000	.004	MIC
1N908	Si	40	40	10	1.0	40000min	up to 40	10	5.0	40000	.004	MIC
MA4230	Si	40	40	10	1.0	1400000min	up to 20	10	5.0	1400000	.004	MIC
PS7267	Si	40		5.0	1.0			5.0	10	20	.15	PSI
PS7268	Si	40		5.0	1.0			5.0	10	20	.15	PSI
PS7269	Si	65		5.0	1.0			5.0	10	20	.15	PSI
PS7270	Si	120		5.0	1.0			5.0	10	20	.15	PSI

VOLTAGE VARIABLE CAPACITOR DIODES

TYPE NO.	CAPACITANCE C @ Eb (uuf)	(volts)	PIV	Q @ FREQ. Min. Q	(mc)	MFR.
MA4255X	.50-1.4	0	6.0	6.0	10000	MIC
MA4256X	1.2-2.5	0	6.0	5.0	10000	MIC
MA4257X	2.5-4.0	0	6.0	3.0	10000	MIC
SVC1	6.5±10per cent	3.0	20	85	50	GECB
SVC2	6.5±20per cent	3.0	20	85	50	GECB
SVC3	6.5±30per cent	3.0	20	85	50	GECB

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from May 7, 1957 to July 9, 1957. In subsequent issues, patents issued from Dec. 25, 1956 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT Review will appear periodically, the treatment given to each item being more detailed.

2,791,731 Metal Rectifier Assemblies—A. H. Walker, D. E. Birch. Assignee: Westinghouse Brake & Signal Co., Ltd. An assembly comprising a block of insulating material with holes therethrough, and a plurality of stacks of metal rectifier elements housed one in each of said holes.

2,791,758 Semiconductive Translating Device—D. H. Looney. Assignee: Bell Telephone Laboratories. A device comprising a body of semiconductive material having a bulk portion of one conductivity type and a surface region of the opposite conductivity type, a ferroelectric material in proximity to said surface region and an electrode spaced from the semiconductor and mounted against the ferroelectric body.

2,791,759 Semiconductive Device—W. L. Brown. Assignee: Bell Telephone Lab-

*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

oratories. A semiconductive body having a gross portion of one conductivity type and a surface portion of the opposite type forming a rectifying junction in the body, a ferroelectric element adjacent to said surface portion, electrodes to opposite sides of the rectifying junction and an electrode to the ferroelectric element.

2,791,760 Semiconductive Translating Device—I. M. Ross. Assignee: Bell Telephone Laboratories. A device of n-p-n type construction having a ferroelectric material in close proximity to a surface portion of the middle zone.

2,791,761 Electrical Switching and Storage —J. A. Morton. Assignee: Bell Telephone Laboratories. A device comprising a body of germanium including an n-p junction, a pair of connections to said body positioned on opposite sides of said junction, and a body of ferroelectric material positioned against the surface of the germanium body in the vicinity of the n-p junction.

May 14, 1957
2,792,489 Final Sealing Apparatus For Semiconductor Translating Devices—F. Wohlman Jr. Assignee: Hughes Aircraft Co. Apparatus for assembling sub-assembly components for semiconductor translating devices wherein such components are accurately held in alignment, are counterbalanced to relieve undesireable loads on delicate components, and are handled in a gentle manner.

2,792,494 Semiconductor Superregenerative Detector—J. J. Suran, W. F. Chow. Assignee: General Electric Company. A super-regenerative detector in which a quench frequency oscillator provides a signal that is applied to the radio frequency oscillator, said signal thereby controlling the period of time in which the radio frequency oscillator operates.

2,792,499 Sawtooth Wave generator--V. P Mathis. Assignee: General Electric Company. A sawtooth wave oscillator comprising an n-type semiconducting body between a pair of base electrodes, a body of p-type material forming a p-n junction with the n-type material in a region between said base electrodes, and reactive electric storage means connected between an additional electrode and one of said base electrodes.

2,792,537 Electrical Apparatus Including One Or More Dry Plate Rectifiers—H. Martin. Assignee: Siemens Schuckertwerke Aktiengesellschaft. Apparatus comprising a thermoplastic supporting body having a hole therein, a stack of disk shaped rectifiers disposed within said hole, and a conductive terminal strip mounted on said body so as to cover said hole.

2,792,538 Semiconductor Translating Device With Embedded Electrode. W. G. Pfann. Assginee: Bell Telephone Laboratories. A signal translating device comprising a body of semiconductive material, a wire connector embedded sidewise in said body and an alloy bond between said body and said connector.

2,792,539 Transistor Construction—K. Lehovec. Assignee: Sprague Electric Co. A transistor comprising a semiconductive body including a p-n junction, low resistance electrodes attached to the p and n regions, and a wire probe extending into a depression in one of said regions, said probe making point contact with the semiconductive material adjacent to said junction.

2,792,540 Junction Transistor—W. G. Pfann. Assignee: Bell Telephone Laboratories. A junction transistor having a surface adjacent base zone with a specific resistivity higher than the bulk portion of the zone and a base electrode making low resistance contact in a region adjacent to the high resistivity portion.

May 21, 1957
2,793,145 Method of Forming a Junction Transistor.—E. N. Clarke. Assignee: Sylvania Electric Products Inc. A method of forming a multiple junction transistor in a manner facilitating control over the thickness of a layer on one conductivity type between regions of the opposite type.

2,793,146 Methods of Treating Germanium —H. I. Crane, P. Wang. Assignee: Sylvania Electric Products Inc. The method of making semiconductor translators by subdividing a germanium ingot into individual units and subjecting such units to prolonged treatment in a molten alkali metal cyanide maintained at a temperature below the melting point of germanium.

2,793,303 Pulse Sharpening Circuits—H. Fleisher. Assignee: International Business Machines Corporation. A circuit in which a transistor conducts and quenches the current which flows through an inductance due to the back emf developed across said inductance upon application of an input pulse, said transistor thereby producing a sharpened pulse across a load impedance.

2,793,331 Semiconductive Devices—J. J. Lamb. Assignee: Sperry Rand Corporation. An electronic control device utilizing a body of semiconductive material, means for enveloping and hermetically sealing said device, and means for shunting current around the semiconductive material when the potential difference between a pair of electrodes reaches a predetermined value.

2,793,332 Semiconductor Rectifying Connections And Methods—B. H. Alexander, R. C. Ingraham. Assignee: Sylvania Electric Products Inc. A rectifier including a semiconductor body of n-type conductivity and a bonded contact primarily of a solid silver alloy containing also smaller amounts of indium or gallium.

May 28, 1957
2,793,420 Electrical Contacts To Silicon—R. L. Johnston, R. L. Rulison. Assignee: Bell Telephone Laboratories. A method of fabricating a low resistance contact to a body of semiconductive silicon by electro-depositing a layer of nickel sufficient to just obliterate the color of said body, heating said body to 800° C in a slightly reducing atmosphere, electrodepositing a second nickel layer, and applying a coating of solder to the nickel plating.

2,794,076 Transistor Amplifiers—R. F. Shea Assignee: General Electric Co. A multi-stage amplifier in which the first stage is operated for stabilization purposes and at a low voltage level, the later stages being operated at a high voltage level, whereby high power output is derived from said amplifier with low power dissipation in the stabilization-producing means.

June 4, 1957
2,794,846 Fabrication of Semiconductor Devices—C. S. Fuller. Assignee: Bell Telephone Laboratories. A method of altering the conductivity of a semiconductor material by applying a glass-forming composition to the surface of said semiconductor, said composition containing at least one significant impurity for the semiconductor, and fuzing said composition at an elevated temperature.

2,794,856 Transistor Keying and Mark Hold Unit—F. T. Turner. Assignee: Western Union Telegraph Co. For use in a radio-telegraph system, a mark-hold unit operating in conjunction with a keying unit in the marking condition during extended periods of received space pulsing.

2,794,863 Semiconductor Translating Device and Circuit—W. W. van Roosbroeck. Assignee: Bell Telephone Laboratories. A translating device comprising substantially intrinsic material in which the difference between the number of free holes and the number of free electrons present is less than the number of free hole-electron pairs.

2,794,864 Non-Reciprocal Circuits Employing Negative Resistance Elements—W. Shockley. Assignee: Bell Telephone Laboratories. In an a-c signal circuit, a two-terminal negative-resistance means coupling said resistance with said signal circuit, a transducer including a three-terminal Hall effect device bridged across said a-c circuit, and circuit means for cancelling out a-c signals transmitted through said Hall effect device in one direction only.

2,794,895 Jig For Making Contact With The Electrodes of a Dry Contact Rectifier —A. H. Walker, L. A. Cole. Assignee: Westinghouse Brake & Signal Co. Ltd. A jig of the kind which is suitable for making contact with the electrodes of a dry contact rectifier element, the contact being made in such a way that heavy current may be passed through the element without damaging it.

2,794,899 Apparatus for And Method Of Forming p-n Junction Devices—A. R. Plummer. Assignee: General Electric Co Ltd. A method of bonding a wire to a fused bead of material which forms a p-n junction with a body of semiconductive material of a predetermined conductivity type.

2,794,917 High Frequency Negative Resistance Device—W. Shockley. Assignee: Bell Telephone Laboratories. A device in which negative signal power dissipation at high frequencies is obtained by transit-time effects of charge carriers in the device.

2,794,942 Junction Type Semiconductor Devices and Method of Making The Same —T. W. Cooper. Assignee: Hughes Aircraft Company. An encapsulated junction-type semiconductor device with an ohmic connecting means to an area of a semiconductor crystal body having a p-n junction therein.

2,794,943 Selenium Rectifier—G. Eannarino R. Parsons. Assignee: Sarkes Tarzian Inc In a selenium rectifier, a barrier layer on the selenium layer, said barrier layer with a dilute solution containing a carbohydrate and an organic amine in an aqueous volatile solvent at a pH between 6.5 and 7.5.

2,794,948 Phase Shifting Circuit—J. H Thompson, R. H. Whittaker. Assignee U.S.A. (Navy Dept.) A network for con

rting an input signal of predetermined equency to a phase-shifted output sig-l of like frequency.

94,952 Within Limits Frequency Re-onse Tester—N. J. Golden, T. Ants T. ip. Assignee: Sylvania Electric Products c. A method of evaluating the fre-iency merit of a transistor without ob-ining any absolute determination of rrent response at any given frequency, id merit being determined on the basis comparison of performance of the ansistor at a reference frequency and at selected higher frequency.

une 11, 1957
795,648 Dielectric Amplifier Employing erro Electric Materials—W. P. Mason. ssignee: Bell Telephone Laboratories. A evice in which a single ferroelectric ondensers, or a part of such condensers, employed in a bridge circuit to which rrier current is applied, a mechanical gnal being simultaneously applied to the ondenser or pair of condensers to vary e electrical unbalance of the bridge cir-uit.

795,717 Cathode Ray Beam Centering pparatus—M. B. Finklestein, B. R. Clay. ssignee: Radio Corporation of America. transistorized beam centering device r use with electromagnetic deflection stems in which the centering control is laced at the center of the deflection yoke.

795,742 Semiconductive Translating De-ices Utilizing Selected Natural Grain oundaries—W. G. Pfann. Assignee: Bell elephone Laboratories. A junction type ermanium transistor comprising two n-pe regions separated by and adjacent to natural grain boundry which occurs in standard n-type germanium ingot, one f said n-type regions having emitter con-ct and the other region having collector ontact.

795,743 Transistor Construction—H. ehovec. Assignee: Sprague Electric Co. point contact transistor, including a oint contact electrode, welded to a semi-onductive body, said welded electrode eing sheathed with an insulating cylin-er of a dielectric resinous material.

795,744 Semiconductor Signal Translat-g Devices—R. J. Kircher. Assignee: Bell elephone Laboratories. A device having p-n junction, point-contact emitter and ollector connections to one of the semi-onductive zones, said connections posi-oned on a line parallel to and spaced bout 0.50 mil from said junction, and mitter being spaced about 2 mils from e collector connection.

795,745 Transistor Unit—G. R. Huard, Jr. ssignee: Motorola, Inc. A transistor unit cluding a flat-surfaced insulating mem-er, a conductive coating on said flat sur-ace, an elongated resilient electrically onductive member secured to at least ne point of said flat surface, a semi-onductive crystal supported by said con-uctive member, and interposed between aid member and said coating.

795,762 Modulation—G. C. Sziblai. As-ignee: Radio Corporation of America. A odulation system in which the imped-nce presented by a semiconductor device the load circuit of a source of carrier ave energy is varied in accordance with odulating signals.

une 18, 1957
796,368 Method of Making Semiconductor Devices—D. A. Jenny. Assignee: Radio Corporation of America. A method involving the immersion of a body of an alloy of lead and a conductive-type determining impurity yielding material in an aqueous solution of acetic acid and hydrogen peroxide, and then alloying said body into a surface of a germanium body of opposite conductivity type than that caused by said impurity.

2,796,512 Assembly Fixture—J. B. Gray III. Assignee: Western Electric Co., Inc. An assembly fixture for assembling elongated electrodes to support wires of header members, said fixture utilizing electrode holding jaws which can be positioned so as to accurately locate the electrodes along the header support wires.

2,796.539 Unidirectional Signal-Conducting System—J. S. Foley. Assignee: International Telephone & Telegraph Corp. A signal conducting and coupling system which will conduct a unipolar signal and a bipolar signal in one direction only.

2,796,562 Semiconductive Device and Method of Fabricating Same—S. G. Ellis, J. I. Pankove. Assignee: Radio Corporation of America. A circuit element comprising a solid semiconductor, an electrode diffused into a portion of one surface of said semiconductor, a rectifying junction, and a high resisting film disposed over a portion of said surface for protecting critical portions of said surface.

2,796,563 Semiconductive Devices—J. J. Ebers, J. J. Kleimads. Assignee: Bell Telephone Laboratories. A device that features a unitary sheet metal electrical connection and mechanical support for a semiconductive body, said sheet metal unit having a raised or depressed area having the same degree of flatness as the body which it engages.

2,796,564 Electric Circuit Element—J. J. Dymon. Assignee: Sylvania Electric Products, Inc. An electric circuit element of the semiconductive type comprising a reduced titanate of an alkaline earth metal having a double layer of freshly skinned and subsequently oxidized surface thereof, consisting of an electrolytically deposited metal oxide coated on a metal oxide paste.

June 25, 1957
2,797,193 Method of Treating the Surface of Solids With Liquids—J. H. Eigler, M. V. Sullivan. Assignee: Bell Telephone Laboratories; A method for stream etching a localized surface area of a semiconductive body while eliminating the need for the application, and subsequent removal of masking materials used in such a process.

2,797,261 Carrier Telegraph Receiver—J. Polyzou. Assignee: International Telephone & Telegraph Corp. Telegraph receiver equipment in which the marking signal is maintained during a period of no signal reception by means of a circuit which causes the receiver amplifier to oscillate at the mark frequency in the absence of received energy.

2,797,267 Transistor Amplifier With Neutralized Internal Feedback—R. R. Yost. Assignee: Motorola, Inc. Circuit means in a transistor amplifier for neutralizing the effect of feedback due to base resistance of the transistor.

2,797,327 Semiconductor Saw Tooth Wave Generator—M. C. Kidd. Assignee: Radio Corporation of America. A balanced push pull sawtooth voltage generator which utilized a single transistor for efficient circuit operation.

2,797,328 Transistor Oscillator—E. G. Miller Jr. Assignee: USA (A.E.C.). A crystal controlled oscillator comprising a pair of transistors a crystal between the base electrodes of said transistors, an antiresonant frequency tuned to the crystal frequency and negative feedback means coupled to the antiresonant circuit.

July 2, 1957
2,798,013 Method of Producing Junction Type Semiconductor Devices and Apparatus Therefore—H. Irmler. Assignee: Siemens-Schuckertwerke Aktiengesellschaft. A method of manufacturing junction type semiconductor devices by contacting a marginal zone of an electrode body with an auxiliary body, allowing the electrode body with the semiconductor, and means for utilizing the surface tension of the molten electrode to maintain the shape thereof.

2,798,160 Power Supply Circuit Using Controllable Electron Solid State Devices—G. Bruck, W. R. Harter, I. M. Wilbur. Assignee: Avco Manufacturing Corporation. In an inverter type power supply, a *d.c.* voltage source, a load circuit, a pair of transistor square wave generators coupled between said source and said load circuit, and means for providing feedback of the in-phase amplified version of the input signal.

2,798,169 Transistor Magnetic Amplifier Bistable Devices—J. P. Eckert, Jr. Assignee: Sperry Rand Corporation. A circuit that has two stable states, one of which is characterized by collector current flow, the other state being characterized by absence of collector current; said circuit including means for causing a transition from one stable state to the other.

2,798,189 Stabilized Semiconductor Devices—B. H. Alexander. Assignee: Sylvania Electric Products. A device including ohmic low resistance connections to a semiconductive body, a pair of point contacts placed so as to effect transistor action, and a boron coating over the surface of said body at the junction of the rectifying connections herewith.

July 9, 1957
2,798,904 Push Pull Magnetic Amplifier—E. F. Alexanderson. Assignee: None. A push-pull magnetic amplifier system consisting of a pair of magnetic amplifiers connected with a common load impedance element, and having means for activating one of said amplifiers to conduct load current, and for providing an open circuit in the unactivated amplifier in response to the load current.

2,798,970 Square Wave Phase Shifter—W. G. Hall, R. I. van Nice. Assignee: Westinghouse Electric Corporation. Apparatus that shifts the phase of a square wave by adding a reference square wave in phase with a second signal comprising a series of rectangular voltage pulses of double the amplitude of the reference signal.

2,798,989 Semiconductor Devices and Methods of Their Manufacture—H. Welker. Assignee: Siemens Schuckertwerke Aktiengesellschaft. A device using a crystal body formed of a compound of an element from group III and group VI of the periodic system.

CHARACTERISTICS CHART of NEW TRANSISTORS

Announced Between Sept. 1, 1959 and Oct. 30, 1959

MANUFACTURERS (In Order of Code Letters)

ARA— Advanced Research Associates, Inc.
AEG— Allgemeine Elecktricitats-gesellschaft
AMP— Amperex Electronic Corp.
AEI— Associated Electrical Industries Export Ltd.
BEN— Bendix Aviation Corp.
BOG— Bogue Electric Mfg. Co.
CBS— CBS-Electronics
CSF— Compagnie Generale
CTP— Clevite Transistor Products, Inc.
DEL— Delco Radio Div., General Motors Corp.
EEVB— English Electric Valve Co., Ltd.
ESEB— Edison Swan Electric Co., Ltd.
FSC— Fairchild Semiconductors Corp.
FTHF— French Thomson-Houston Semiconductor Dept.
GECB— General Electric Co., Ltd.
GE— General Electric Co.
GEM— Great Eastern Mfg. Co.
GTC— General Transistor Corp.
HUG— Hughes Aircraft Co.
HIVB— Hivac Ltd.
IND— Industro Transistor Corp.
LCTF— Labortoire Central de Telecommunications
MIN— Minneapolis-Honeywell Regulator Co.
MOT— Motorola, Inc.
MUL— Mullard Ltd.
NTLB— Newmarket Transistors Ltd.
NPC— Nucleonics Products Co.
PSI— Pacific Semiconductors, Inc.
PHI— Philco Corp., Landsdale Tube Co.
RAY— Raytheon Co.
RCA— Radio Corp. of America, Semiconductor Div.
RHE— Rheem Semiconductor Corp.
SIE— Siemens & Halske Aktiengesellschaft
SIL— Silicon Transistor Corp.
SONY— Sony Corp.
SPE— Sperry Gyroscope Co.
SPR— Sprague Electric Co.
SYL— Sylvania Electric Products Inc.
STCB— Standard Telephone & Cables, Ltd.
TKAD— Suddeutsche Telefon-Apparate-, Kabel und Drahtwerke
TRA— Transitron Electronic Corp.
TFKG— Telefunken Ltd.
TI— Texas Instruments
TUN— Tung-Sol Electric, Inc.
UST— U. S. Transistor Corp.
WEC— Western Electric Co., Inc.
WEST— Westinghouse Electric Corp.

The following manufacturers have announced that they have begun supplying the indicated previously registered transistors.

BENDIX: 2N155, 2N176, 2N242, 2N257, 2N268, 2N268A, 2N297, 2N301, 2N301A, 2N1011
HUGHES: 2N1219
MOTOROLA: 2N297A, 2N404
PHILCO: 2N129, 2N300
RAYTHEON: 2N1017
RHEEM: 2N497, 2N498, 2N656, 2N657, 2N696, 2N697
SPERRY: 2N327A, 2N328A, 2N329A, 2N330A, 2N1034, 2N1035, 2N1036, 2N1037, 2N1219, 2N1220, 2N1221, 2N1222, 2N1223, 2N1275
TEXAS INSTRUMENTS: 2N696, 2N697
TRANSITRON: 2N118, 2N118A, 2N119
U.S. TRANSISTOR: 2N315, 2N316, 2N317, 2N359, 2N360, 2N361, 2N362, 2N363, 2N398, 2N404, 2N413, 2N413A, 2N414, 2N414A, 2N416, 2N417, 2N422, 2N425, 2N426, 2N427, 2N428, 2N464, 2N465, 2N466, 2N467, 2N482, 2N483, 2N484, 2N485, 2N486
WESTINGHOUSE: 2N1195

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. See code at end of chart
				P_c (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha\beta}$ (mc)	Gain: PARAMETER and (condition)	Gain: VALUE	
2N43A	2⍁	PNPA	Ge	240	.25	45	30	1.3	h_{fe}:I_e-1.0ma	42	GE
2N332A	2⍁	NPNG	Si	500	.30	45	45	10	h_{fe}:1.0ma	16	GE
2N333A	2⍁	NPNG	Si	500	.30	45	45	11	h_{fe}:1.0ma	30	GE
2N334A	2⍁	NPNG	Si	500	.30	45	45	12	h_{fe}:1.0ma	38	GE
2N335A	2⍁	NPNG	Si	500	.30	45	45	13	h_{fe}:1.0ma	52	GE
2N336A	2⍁	NPNG	Si	500	.30	45	45	15	h_{fe}:1.0ma	95	GE
2N528	3,5	PNPA	Ge	2500	30	40	40	4.0	h_{FE}:I_c-.50A	20 min	WEC
2N537	2	PNPMe	Ge	250	330	30	1.0	750	h_{fe}:I_c- 10ma	10db min	WEC
2N650A	2,5	PNPA	Ge	200		45	30		h_{fe}:I_E-1.0ma	30 min	MOT
2N651A	2,5	PNPA	Ge	200		45	30		h_{fe}:I_E-1.0ma	50 min	MOT
2N652A	2,5	PNPA	Ge	200		45	30		h_{fe}:I_E-1.0ma	100min	MOT
2N677	3,5⍁	PNP	Ge	50W	1.5	50	30		h_{FE}:I_c- 10A	40	BEN
2N677A	3,5	PNP	Ge	50W	1.5	60	40		h_{FE}:I_c- 10A	40	BEN
2N677B	3,5	PNP	Ge	50W	1.5	90	70		h_{FE}:I_c- 10A	40	BEN
2N677C	3,5	PNP	Ge	50W	1.5	100	80		h_{FE}:I_c- 10A	40	BEN
2N678	3,5⍁	PNP	Ge	50W	1.5	50	30		h_{FE}:I_c- 10A	75	BEN
2N678A	3,5⍁	PNP	Ge	50W	1.5	60	40		h_{FE}:I_c- 10A	75	BEN
2N678B	3,5⍁	PNP	Ge	50W	1.5	90	70		h_{FE}:I_c- 10A	75	BEN
2N678C	3,5⍁	PNP	Ge	50W	1.5	100	80		h_{FE}:I_c- 10A	75	BEN
2N694	2,4	PNPMe	Ge	100	750	30	15	750	h_{fe}:I_c-2.0ma	10db min	WEC

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C: P_c (mw)	Max. Ratings @ 25° C: DERATING °C/W	Max. Ratings @ 25° C: V_{CB}	Max. Ratings @ 25° C: V_{CE}	Typical Characteristics: $f_{\alpha\beta}$ (mc)	Typical Characteristics: Gain: PARAMETER and (condition)	Typical Characteristics: Gain: VALUE	MFR. See code at end of chart
2N702	2,5⍁	NPNMe	Si	600		25	25		h_{FE}:I_c- 10ma	60 max	TII
2N703	2,5⍁	NPNMe	Si	600		25	25		h_{FE}:I_c- 10ma	100max	TII
2N1015	3	NPN	Si		.70	30	30		h_{fe}:I_c-2.0A	10 min	WEST
2N1015A	3	NPN	Si		.70	60	60		h_{fe}:I_c-2.0A	10 min	WEST
2N1015B	3	NPN	Si		.70	100	100		h_{fe}:I_c-2.0A	10 min	WEST
2N1015C	3	NPN	Si		.70	150	150		h_{fe}:I_c-2.0A	10 min	WEST
2N1015D	3	NPN	Si		.70	200	200		h_{fe}:I_c-2.0A	10 min	WEST
2N1016	3	NPN	Si		.70	30	30		h_{fe}:I_c-5.0A	10 min	WEST
2N1016A	3	NPN	Si		.70	60	60		h_{fe}:I_c-5.0A	10 min	WEST
2N1016B	3	NPN	Si		.70	100	100		h_{fe}:I_c-5.0A	10 min	WEST
2N1016C	3	NPN	Si		.70	150	150		h_{fe}:I_c-5.0A	10 min	WEST
2N1016D	3	NPN	Si		.70	200	200		h_{fe}:I_c-5.0A	10 min	WEST
2N1031	3,5⍁	PNP	Ge	50W	1.5	50	30		h_{FE}:I_c- 10A	40	BEN
2N1031A	3,5⍁	PNP	Ge	50W	1.5	60	40		h_{FE}:I_c- 10A	40	BEN
2N1031B	3,5⍁	PNP	Ge	50W	1.5	90	70		h_{FE}:I_c- 10A	40	BEN
2N1031C	3,5⍁	PNP	Ge	50W	1.5	100	80		h_{FE}:I_c- 10A	40	BEN
2N1032	3,5⍁	PNP	Ge	50W	1.5	50	30		h_{FE}:I_c- 10A	75	BEN
2N1032A	3,5⍁	PNP	Ge	50W	1.5	60	40		h_{FE}:I_c- 10A	75	BEN
2N1032B	3,5⍁	PNP	Ge	50W	1.5	90	70		h_{FE}:I_c- 10A	75	BEN
2N1032C	3,5⍁	PNP	Ge	50W	1.5	100	80		h_{FE}:I_c- 10A	75	BEN
2N1051	3	NPNMe	Si	600	250	5.0	40	140	h_{fe}:I_E-5.0ma	18db min	WEC
2N1078	3	PNP	Ge	20W	3.0	60	45		h_{FE}:I_c-.50A	30 min	CBS
2N1149	2	NPNG	Si	150	.840	45	25	4.0	h_{fe}:I_e-1.0ma	13	TII
2N1150	2	NPNG	Si	150	.840	45	25	5.0	h_{fe}:I_e-1.0ma	24	TII
2N1151	2	NPNG	Si	150		45	25	8.0	h_{FE}:I_c- 10ma	65	TII
2N1152	2	NPNG	Si	150		45	25	6.0	h_{fe}:I_e-1.0ma	63	TII
2N1153	2	NPNG	Si	150		45	25	7.0	h_{fe}	200	TII
2N1154	3	NPNG	Si	750	.170	50	60	1.0	h_{fe}:I_e-5.0ma	15	TII
2N1155	3	NPNG	Si	750	.170	80	50	1.0	h_{fe}:I_e-5.0ma	15	TII
2N1156	3	NPNG	Si	750	.170	40	40	1.0	h_{fe}:I_e-5.0ma	15	TII
2N1196	4	DMe	Si	250	550	40	40	45	PG:I_E-2ma;4.3mc	26db	HUG
2N1197	4	DMe	Si	250	550	40	40	75	PG:I_E-2ma;12.5mc-	22db	HUG
2N1205	2	NPN	Si	150		20	20		h_{fe}:I_e-2.0ma	6	TRA
2N1320	3	PNP	Ge	20W	3.0	35	30		h_{FE}:I_c-.50A	30 min	CBS
2N1321	3	NPN	Ge	20W	3.0	35	30		h_{FE}:I_c-.50A	30 min	CBS
2N1322	3	PNP	Ge	20W	3.0	60	45		h_{FE}:I_c-.50A	30 min	CBS
2N1323	3	NPN	Ge	20W	3.0	60	45		h_{FE}:I_c-.50A	30 min	CBS
2N1324	3	PNP	Ge	20W	3.0	80	60		h_{FE}:I_c-.50A	30 min	CBS
2N1325	3	NPN	Ge	20W	3.0	80	60		h_{FE}:I_c-.50A	30 min	CBS
2N1326	3	PNP	Ge	20W	3.0	100	80		h_{FE}:I_c-.50A	30 min	CBS
2N1327	3	NPN	Ge	20W	3.0	100	80		h_{FE}:I_c-.50A	30 min	CBS
2N1328	3	PNP	Ge	20W	3.0	35	30		h_{FE}:I_c-.50A	30 min	CBS
2N1329	3	NPN	Ge	20W	3.0	35	30		h_{FE}:I_c-.50A	30 min	CBS
2N1330	3	NPN	Ge	20W	3.0	60	45		h_{FE}:I_c-.50A	30 min	CBS
2N1331	3	PNP	Ge	20W	3.0	80	60		h_{FE}:I_c-.50A	30 min	CBS
2N1332	3	NPN	Ge	20W	3.0	80	60		h_{FE}:I_c-.50A	30 min	CBS
2N1333	3	PNP	Ge	20W	3.0	100	80		h_{FE}:I_c-.50A	30 min	CBS
2N1334	3	NPN	Ge	20W	3.0	100	80		h_{FE}:I_c-.50A	30 min	CBS

NOTATIONS

Under Use

1 - Low power a-f equal to or less than 50 mw
2 - Medium power a-f > 50 mw and equal to or less than 500 mw
3 - Power > 500 mw
4 - r-f/i-f
5 - Switching and Computer
6 - Low Noise
7 - Photo
8 - Mixer
9 - Local Oscillator

⍁ - Revised Spec.

Under Type

A - Alloyed
D - Diffused or Drift
F - Fused
G - Grown
H - Hook Collector
M - Microalloy
Me - Mesa
O - Other
S - Surface Barrier
UNI - Unijunction Transistor
Y - Symmetrical
t - Tetrode

Under f_{ab}

* Maximum Frequency
\# Figure of Merit
△ $f_{\alpha e}$
Ø Minimum
† f_T = Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under P_c

Ø - Infinite heat sink

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C: P_c (mw)	DERAT-ING °C/W	V_{CB}	V_{CE}	$f_{\alpha\beta}$ (mc)	Typical Characteristics — Gain: PARAMETER and (condition)	VALUE	MFR. (See code at end of chart)
2N1385	3	PNPMe	Ge	750		25		700	h_{fe}:10ma;100Mc-8min		TII
2N1428	4,5	PNPO	Si	100	77	6.0	6.0	42	h_{fe}:I_c-1.0ma	45	PHI
2N1429	4,5	PNPO	Si	100	77	6.0	6.0	42	h_{fe}:I_c-1.0ma	45	PHI
2N1431	2	NPNA	Ge	180	278	20	15	.01△	h_{FE}:I_C- 35ma	112	SYI
2N1432	2	PNPD	Ge	100	750	45		.01△	h_{FE}:I_C-2.0ma	60	SYL
2N1433	3	PNPA	Ge	35W	2.0	80	50	.20∅	h_{FE}:2.0A	20-50	CBS
2N1434	3	PNPA	Ge	35W	2.0	80	50	.20∅	h_{FE}:2.0A	30-75	CBS
2N1435	3	PNPA	Ge	35W	2.0	80	50	.20∅	h_{FE}:2.0A	45-115	CBS
2N1437	3	PNPA	Ge	35W	3.0	100	80		h_{FE}:.50A	40	CBS
2N1438	3	PNPA	Ge	35W	3.0	100	80		h_{FE}:.50A	40	CBS
800	2,7	NPN	Ge	65							TII
OD650	3∅	PNPA	Ge	45W	1.0	60	25	.10	h_{FE}:I_c- 15A	10 min	AEG
OD650B	3	PNPA	Ge	45W	1.0	60	25	.10	h_{FE}:I_c- 15A	15 min	AEG
OD651	3∅	PNPA	Ge	45W	1.0	60	40	.10	h_{FE}:I_c- 15A	10 min	AEG
OD651A	3∅	PNPA	Ge	45W	1.0	60	30	.10	h_{FE}:I_c- 15A	10 min	AEG
OD652	3	PNPA	Ge	45W	1.0	60	15	.10	h_{FE}:I_c- 30A	10 min	AEG
ST9	2	NPN	Si	150		15	15		h_{fe}:I_e-1.0ma	11	TRA
ST29	2	NPN	Si	150		30	30		h_{fe}:I_e-1.0ma	11	TRA
ST35	2	NPN	Si	200		30	30		h_{fe}:I_e-1.0ma	11	TRA
STC389	3	NPND	Si	85W	1.8		60	2.0	h_{FE}:I_c-1.5A	20	SIL
STC1001	3	NPND	Si	50W	3.0	100	60	1.0	h_{FE}:I_c-1.5A	20	SIL
ST1026	1	NPN	Si	30		6.0	6.0	5.0	h_{fe}:I_c-110ma	70	TRA
TK41	2	PNPA	Ge	200	.25	40		.90	h_{fe}:I_c-1.0ma	40	STCB
TK42	2	PNPA	Ge	200	.25	40		1.4	h_{fe}:I_c-1.0ma	70	STCB
UST10	5	PNPA	Ge	180	360		50		h_{fe}:I_E-1.0ma	22	UST
UST19	5	PNPA	Ge	180	360		25	1.5	h_{fe}:I_E-1.0ma	80	UST
UST81	2	PNPA	Ge	180	360		25		h_{fe}:I_E-1.0ma	90	UST
UST87	5	PNPA	Ge	180	360		25	.50	h_{fe}:I_E-1.0ma	38	UST
UST88	5	PNPA	Ge	180	360		25	1.0	h_{fe}:I_E-1.0ma	80	UST
UST722	2	PNPA	Ge	180	360		20		h_{fe}:I_E-1.0ma	22	UST
UST760	2	PNPA	Ge	160	400		15	5.0	h_{fe}:I_E-1.0ma	40	UST
UST761	2	PNPA	Ge	160	400		10	10	h_{fe}:I_E-1.0ma	75	UST
UST762	2	PNPA	Ge	160	400		10	20	h_{fe}:I_E-1.0ma	100	UST
UST763	2	PNPA	Ge	160	400		6.0	30	h_{fe}:I_E-1.0ma	120	UST
UST764	2	PNPA	Ge	160	400		20	25	h_{fe}:I_E-1.0ma	200	UST
XA123	4,8	PNPAD	Ge	80	750	20		30	h_{fe}:I_e-1.0ma	60	ESEB
XA124	4,9∅	PNPAD	Ge	80	750	20		30	h_{fe}:I_e-1.0ma	60	ESEB
XA126	4	PNPAD	Ge	80	750	20		30	h_{fe}:I_e-1.0ma	60	ESEB
XA131	4∅	PNPAD	Ge	120	500	30		100	h_{fe}:I_e-1.5ma	60	ESEB
XA141	5∅	PNPAD	Ge	120		30		30†	h_{FE}:I_e-5.0ma	45	ESEB
XA142	5∅	PNPAD	Ge	120		30		50†	h_{FE}:I_e-5.0ma	45	ESEB
XA143	5∅	PNPAD	Ge	120		30		75†	h_{FE}:I_e-5.0ma	45	ESEB
XC141	3∅	PNPA	Ge	11W	1.0	40			h_{fe}:I_e-.70ma	62.5	ESEB
XC142	3∅	PNPA	Ge	11W	1.0	60			h_{fe}:I_e-.70ma	62.5	ESEB
XC155	3∅	PNPA	Ge	50W	1.0	80			h_{FE}:I_c-1.0A	75	ESEB
XC156	3∅	PNPA	Ge	50W	1.0	100			h_{FE}:I_c-1.0A	75	ESEB

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Under Type

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Y - Symmetrical
‡ Tetrode

Under f_{ab}

* Maximum Frequency
\# Figure of Merit
△ $f_{\alpha e}$
∅ Minimum
† f_T = Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Under P_c

∅ - Infinite heat sink

PHILCO ANNOUNCES...

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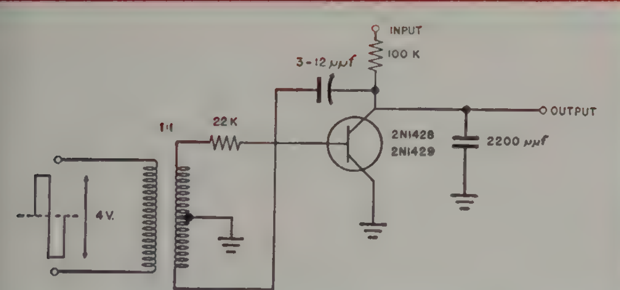
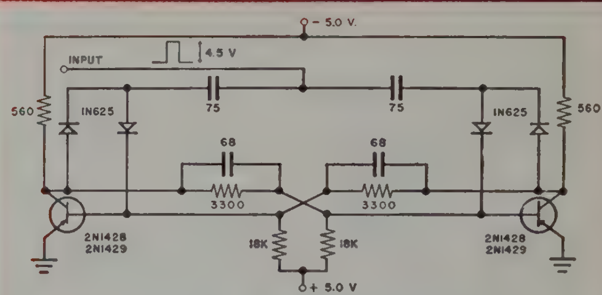
SAT* 2N1428...2N1429

Stable at Temperatures up to 140° C



LOW LEVEL (<1MV) CHOPPER



1 MC BINARY STAGE (−55°C TO +125°C)

These two new Philco PNP Silicon Surface Alloy Transis-tors are designed for general purpose high frequency amplifying and switching applications. They offer ex-tremely low saturation resistance (approaching that of germanium transistors) . . . high f_T . . . low leakage current . . . good inverse Beta . . . low offset voltage . . . and excel-lent frequency response. The combination of high Beta and low I_{CO} makes these transistors excellent for use in DC amplifiers, low level choppers and other critical con-trol circuits. They are suitable for:

. . . high speed switches, operating at speeds up to 5 mc.
. . . general purpose high frequency amplifiers.
. . . DC amplifiers.
. . . high input impedance low frequency amplifiers and choppers.

These two transistors are electrical equivalents, but offer a choice of packages . . . the popular small TO-1 package and the standard TO-5 package. Designers of industrial control and test equipment will find that they deliver excellent performance at high ambient temperatures. **Write Dept. SC-160 for complete information and application data.**

*SAT . . . trademark PHILCO Corporation for Surface Alloy Transistor

Absolute Maximum Ratings

Storage Temperature	−65 to +140° C
Junction Temperature	+140° C
Collector to Base Voltage, V_{CB}	−6 volts
Collector to Emitter Voltage, V_{CEO}	−6 volts
Collector Current, I_C	−50 ma
Total Device Dissipation at 25° C (Note 2)	100 mw

mmediately Available in Production uantities...and from 1 to 99 from our local Philco Industrial Semi-nductor Distributor.

PHILCO®

LANSDALE DIVISION • LANSDALE, PENNSYLVANIA

Circle No. 16 on Reader Service Card

Industry News

CONFERENCE CALENDAR

The Following February 1960 Meetings Are Scheduled:

Feb 3-5 PGMIL Winter Meeting, Ambassador Hotel, Los Angeles. Sponsored by PGMIL. For Information: Gordon B. Knoob, Motorola, Inc., Military Electronics Div., 1741 Ivar, Hollywood, Calif.

Feb 10-12 Solid State Circuits Conference, University of Pennsylvania, Philadelphia. Sponsored by PGCT, AIEE, University of Pa. For Information: Tudor R. Finch, Bell Telephone Labs, Murray Hill, N. J.

Feb 25-26 Scintillation Counter Symposium, Washington, D. C. Sponsored by PGNS, AIEE, AEC, NBS. For Information: George A. Morton, RCA Labs, Princeton, N. J.

Feb 25-26 Semiconductor Group, American Society For Testing Materials, Washington, D. C. For Information: J. B. Milgram, Jr., Foote Mineral Company, 18 W. Chelten Ave., Philadelphia 44, Pa. (Victor 8-4000).

RESEARCH & DEVELOPMENT

Precision needs of the military services and industry are now outstripping the availability of standards and calibration services in the radio-electronics field. Manufacturers have attempted to fill the gap by establishing procedures to calibrate their own working standards, but these standards lose much of their value if they are not calibrated in terms of national standards. In an effort to meet these urgent needs, the NBS Radio Standards Laboratory in Boulder, Colorado, is expanding its program of radio standards research and calibration services. A detailed study of polarization and conductivity in crystals of barium titanate has led to formulas that consider the presence of free charges near the domain walls. These equations explain variation in hysteresis loop shape, the dependence of conductivity on polarization, and the variation of switching time with various parameters. In conductivity studies they are investigating the tensor of directional conductivity of semiconductors such as single crystals of germanium at microwave frequencies under different physical conditions. These studies are expected to yield a better understanding of the crystal-lattice forces and processes.

A new type of infrared detector, so sensitive that it can track space satellites and detect intercontinental ballistic missiles at "extreme" distances, was announced recently by Hughes Aircraft Company. Dr. Robert M. Talley, manager of the infrared laboratory of Hughes' Santa Barbara Research Center, said the device, a copper-doped germanium

·ystal, that operates at the temperature of liquid hydro-
ən, is six times as sensitive as other existing detectors in
ıe 8-to-25 micron range. "Laboratory tests show that the
ew infrared detector responds in microseconds to very
nall temperature changes and makes it possible to detect
ırgets at extreme distances," Dr. Talley said. "The short
me constant of the detector recommends it for use in high
peed surveillance systems.

An automatic pilot with no moving parts is being devel-
ped by the Bendix Aviation Corporation, it was an-
ounced in Dallas recently at the National Automatic Con-
rol conference. New developments in solid-state electronic
ircuitry now make it possible to eliminate all electron-
ally actuated mechanical devices between the "input
ensors" and "muscles," or output servos, of aircraft flight
ontrol systems, according to engineers of the corporation's
clipse-Pioneer division who attended the conference.
he developments were described in three technical
apers covering electronic switching, electronic control of
light control system gains, and electronic integration and
ignal filtering. They will mean the virtual elimination of
uch time-honored devices as rotating shafts, gear trains,
ams, motors, and relays.

A major breakthrough in long-range missile and space
ehicle tracking through the use of an all solid-state,
40-MC beacon transponder system was announced re-
ently by W. F. Joyce, Vice President in charge of the
Apparatus division of Texas Instruments Inc. Installed
n an Air Force Thor-Able Missile on September 17th, the
eacon transponder system responded from 1300 miles
n space to an MIT Lincoln Laboratories Millstone Radar
which tracked the missile from horizon to horizon during
4 minutes of its flight. The new system is capable of 40
ours continuous operation on self-contained batteries,
weighs only 6.3 pounds, and occupies only 0.058 cubic
eet. A key factor in designing the system was the devel-
pment by Texas Instruments of a new series of *uhf* tran-
istors which made possible complete miniaturization of
he transponder.

Custom design of microwave maser amplifiers for ad-
anced systems applications, offering significant advan-
ages for extremely long-range systems such as space ve-
icle communications and tracking, radio astronomy and
round-to-ground communications via satellites, was an-
ounced recently by Hughes Aircraft Company. Hughes
cientists said that amplifier noise temperatures of less
han 10° Kelvin are now possible in the 1-to-15 KMc band
or amplifiers having gains and band-widths typically be-
ween 20 and 30 db and 5 to 30 Mc, respectively. Thus it
s possible, they said, to achieve overall receiver noise
emperatures, not including the noise output of the an-
enna, of 10° Kelvin. This contrasts with the value of 1500°
Kelvin for the noise temperature of a good conventional
nicrowave receiver having an 8 db noise figure. An im-
ortant advance is the development of multiple-cavity
nasers in which each cavity consists of a silver-plated
uby crystal, they said. The operation of this type of ampli-
ier is analogous to that of a synchronously tuned multiple-
avity filter having a power gain in each section. The addi-
ion of a second cavity to a conventional single-cavity
naser increases the band-width from 5 Mc to 18 Mc when
he overall gain is adjusted to 26 db in each case. A third
avity provides a small additional improvement, as is ex-
ected from the theory for the behavior of such circuits.

SUBSCRIBE TO SEMICONDUCTOR PRODUCTS TODAY!

MARKET

Distributors

National Semiconductor Corporation of Danbury, Conn., has opened a western regional office in El Segundo, Cal.

Clevite Transistor Products, Waltham, Mass., has named the following two new distributors: Semiconductor Specialists Inc., Chicago, Ill., who will serve Illinois, Michigan and Indiana. Burnstein-Applebee Co., Kansas City, Mo., who will serve Kansas, Iowa and Missouri.

Hughes Aircraft Company has opened four new regional sales offices for its semiconductor division. These offices are located in Orlando, Fla., San Diego, Cal., Englewood, Col., and Silver Spring, Md.

Motorola's Semiconductor Products Division has opened a new district sales office in Detroit for the marketing areas in Michigan and Northern Ohio.

Expansions

Hoffman Electronics Corporation has opened its $2 million Hoffman Semiconductor Center in El Monte, Cal. This new unit will house the headquarters of the Semiconductor Division which has been moved from Evanston, Ill. The Evanston unit will be expanded as a manufacturing base for Hoffman Zener diodes and other control regulators.

Clevite Transistor Products, Waltham, Mass., started construction on a $4.1 million dollar plant expansion program which is scheduled to be completed next June. The new building will have 165,000 square feet of laboratory, production and office space. It is planned to add 1,500 engineers, production workers and office personnel when the unit is completed.

Hughes Aircraft Company, Culver City, Cal., expects to begin production of semiconductors and other components, next fall, in a new $1 million plant to be built in Glenrothes, Scotland, by 1962. The company expects to employ 500 people at Glenrothes.

The regional office of Texas Instruments in Chicago has been relocated and combined with its newly acquired Metals and Control Corporation.

Radio Corporation of America has realigned the organization of its Semiconductor and Materials Division in Sommerville, N.J., to include four product departments: Entertainment Semiconductor Products, Industrial Semiconductor Products, Computer Products and Micromodules. The division's marketing department will handle the combined marketing and sales for all product lines.

Financial

Tang Industries, Waltham, Mass., has recently offered 160,000 common shares of stock for sale at $3 per share. This firm was organized last May and is engaged in the production and distribution of semiconductor materials and devices.

The Board of Directors of Philco Corporation has issued their regular quarterly dividend of 93¾ cents per share on the company's preferred stock, and 25 cents per share on the common stock.

Transitron, Wakefield, Mass., recently sold 1,000,000 shares of common stock to the public for $36 per share.

Clevite Corporation has reported a net income, for the first nine months of its current fiscal year, of more than double that of a year ago. For this period a net income of $4,811,654 earned $2.51 per share as against $2,116,792 and $1.08 per share last year.

Tung-Sol Electric Inc., for the 39 week period ending in September has reported an increase in sales and profits over last year. This year's figures are: Sales $53,088,119, Profits $2,109,654; as against last year's figures of: Sales $43,002,356, Profits $1,768,922.

Industro Transistor Corporation, New York reported a net profit of $128,656, which is equal to 24 cents per share for the three months period ending September 30.

NEWS...

Accurate Specialties Company, Inc., Woodside, N.Y., releasing ıeir first quarterly report since their public offering in June ı59, report sales of $218,308 with a net profit before federal inome taxes of $14,400. The company has an unfilled order backg for semiconductor preforms and components of $212,000 as ompared with $65,000 a year ago.

Texas Instruments has reported that sales and earnings for ıe third quarter of this year are the highest in the history f the company. Net earnings for this period was 89 cents per ommon share as against 44 cents per common share for the ame period in 1958.

	Sales	
Period	1959	1958
ıird quarter	$46,700,000	$21,867,000
ine months	$140,899,000	$64,056,000
	Earnings	
Period	1959	1958
ıird quarter	$3,572,000	$1,448,000
ine months	$9,877,000	$3,591,000

'rices

Raytheon Company has announced price reductions of 5 to 35% n 23 types of transistors. The 35% price reduction applies to our PNP germanium devices; 2N658, 2N660-62. Several different ypes of silicon resistors have been reduced up to 20%. The ve percent reduction applies to prices of 11 germanium tranistors used in audio and radio receiver applications.

General Electric Company, Syracuse, N.Y., has four new high requency NPN silicon transistors in production. These transisors are designed for general purpose amplifier and switching use. ll have a minimum alpha cutoff frequency rating of 15 mc. In arge quantities prices range from $5.90 each for the 2N1276 in 14.80 each for the 2N1279.

ales

The Commerce Department reports that the sale of semiconuctor devices for the first half of 1959 surpasses the dollar alue of all other electronic components except receiving tubes. he estimated sale of semiconductors for this period was #177.2 nillion which is slightly over 94% of the $188.1 million sale f receiving tubes. Semiconductor shipments during this period vere more than double those of the same period last year, vhile receiving tube shipments increased only 5%. Approxiıately 76% of the semiconductors sold went into non-military se.

The EIA reports that the factory sales of transistors alone or the first nine months of 1959 has reached 57,910,513 units as ompared with 30,387,277 during the same period of 1958. Sales uring September reached an all time monthly record of 8,652,526 s against 5,076,443 during September 1958. Sales during Septemer alone were more than double the number of units sold uring the entire calendar year 1955.

uppliers

Anchor Metals Inc., N.Y., producers of solders and fluxes has stablished a new firm, Anchor Alloys Inc., which will specialize n the manufacture of precious alloys for use in producing ransistors, diodes and other semiconductor devices.

Semimetals, N.Y., has reduced its price on doped single crystal ermanium from $650 to $629 a kilo. Crystals are available from 000 dislocations per cm² down to 2,000 dislocations per cm².

Accurate Specialties Co., Inc., N.Y., has formed a subsidiary ligh Purity Metals, Inc., to specialize in the production of raw ıaterials used in semiconductor devices. The new company will oon market indium gallium and other metals in ingot form in urities up to 99.999%.

Consolidated Mining and Smelting Company of Montreal, 'anada has announced a reduction in price of their Special esearch Grade Indium from $22 to $16 per troy ounce. In uantities of 200 troy ounces or over the new price is $14.50 per roy ounce.

NEW SERVICE NOW AVAILABLE

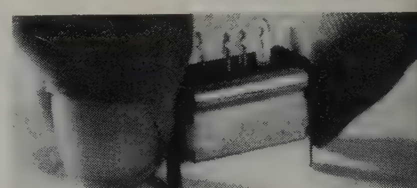
Beginning with this issue, the sales department of SEMICONDUCTOR PRODUCTS is making a new source of information available to all firms interested in being kept up to date on materials or equipment for producing semiconductor devices. If you wish to receive all new literature on silicon, germanium, chemicals, machinery, or other such materials, circle #99 on the reader-service card. Your name will be placed on a special list which will be forwarded to all such suppliers. As these suppliers have news available in their field, you'll be notified by them immediately. This service is restricted to firms manufacturing semiconductor devices or firms contemplating entering into production within 120 days.

New Products

Selenium Rectifier "Flat"

A new miniature selenium rectifier bridge assembly, 1/5 to 1/10 the size of conventional devices of its kind, and "packaged" for maximum ease of mounting in a wide range of commercial electronic products, is now available in production quantities from the Selenium Division of Radio Receptor Company, Inc., subsidiary of General Instrument Corporation. Designed to operate directly off line voltage, and rated 155 vrms maximum at 90 ma d.c., it combines four selenium elements in a package only 13/16" x 7/8" x 15/32".

Circle 102 on Reader Service Card



Fused Silicon Diodes

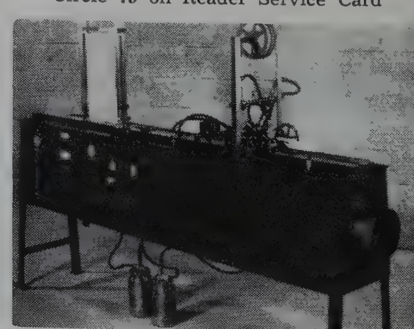
Fused silicon diodes, types 1N645 to 1N649, with lower reverse leakage have been developed and are in production at Hughes Aircraft Company's semiconductor division. The units have a power dissipation rating (at 25° C) of 600 mW, putting them in the medium power classification. Peak inverse voltage (at −65° to +150° C) varies from 225 volts for type 1N645 up to 600 volts for type 1N649. The remaining types are rated at 100 volt intervals. Minimum average rectified forward current is 400 mA at 25° centigrade derated to 150 mA at 150° C.

Circle 77 on Reader Service Card

Automatic Spraying Machine

Conforming Matrix Corporation has announced the development of a completely automatic machine for rapidly applying coating compounds to small articles such as electrical and electronic components. Among its uses are the accurate encapsulating of diodes with sprayable coating materials at a rate of 4000 per hour. A resinous composition, such as an epoxy compound, can be used to completely form a light-tight seal for selenium diodes provided the coating material is sprayable.

Circle 75 on Reader Service Card



Box Type Furnaces

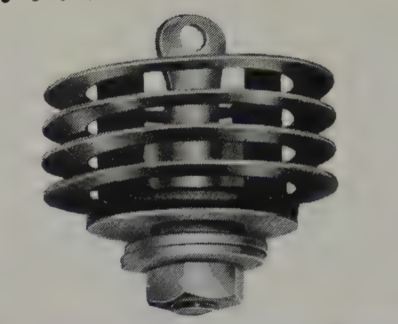
Noticeably different because of features that provide rapid solution to heat-treating problems, especially in the chemical, metallurgical and industrial applications, are Blue M Electric Stabil-Glow Box-Type Furnaces. When set temperature is reached, wattage is automatically reduced to stabilize oven temperature. Continuous Temperature: To 2000°F. (1093°C.). Completely Automatic.

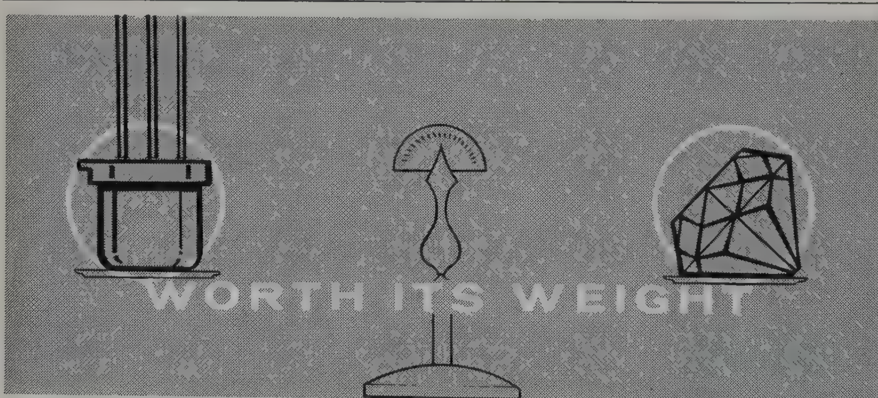
Circle 106 on Reader Service Card

Mechanical Washer

The development of a small portable mechanical mask washing machine has been announced by Conforming Matrix Corporation. Model W-1500-S effectively washes masks up to 10″ x 10″ in a matter of seconds, cleaning them by violent agitation of the solvent. Motivation is by an air motor requiring from 2 to 7 C.F.M. The solvent tank has a capacity of approximately 7 gallons. Installation is made by connecting a ¼″ air hose to the motor.

Circle 76 on Reader Service Card





PNP GERMANIUM ALLOY TRANSISTORS	TYPE #	F α CB mc	Cc μμf	DC gain	VCE max. volt
		TYPICAL CHARACTERISTICS @ 25°C			
COMPUTING and SWITCHING	2N404	5	12	80	−25
	2N425 thru 2N428	3 – 17	12	30 – 100	−20 – −12
R.F. RADIO TYPES	2N413 thru 2N417	2.5 – 20	12	25 – 100	−18 – −10
	2N481 thru 2N486	2.5 – 20	12	25 – 100	−12 – −10

New Packaging

Precision components and solder preforms for the electronic and semiconductor industries are now protected from distortion and other damage in shipment by a new package devised by Alpha Metals. This new package is one of several such improvements designed to insure receipt of parts in condition for use and thus help the manufacturer increase his semiconductor yield. Another Alpha development is the packaging of semiconductor device materials in gases or liquids to prevent oxidation and necessary cleaning prior to use.

Circle 86 on Reader Service Card

Silicon Transistor

Four new high frequency NPN silicon transistors for use in military and industrial equipment have been announced by the General Electric Company. They have a minimum alpha cutoff frequency rating of 15-megacycles. Collector to base voltage ratings on the new line is 40-volts. The temperature range of the transistors is from −65°C to +200°C.

Circle 88 on Reader Service Card

Polyester Film Capacitors

A Most Reliable 'wrap-and-endfill' polyester film capacitor is the Sprague Electric Type 158P Yellow-Jacket Filmite 'E' Capacitor for military and industrial electronics. Light-weight, minimum size. They offer attractive advantages to equipment designers for applications requiring good reliability in service. Designed To Withstand a 250 hour accelerated life test of 150% of the 85°C rated voltage impressed or the equivalent derated 125°C

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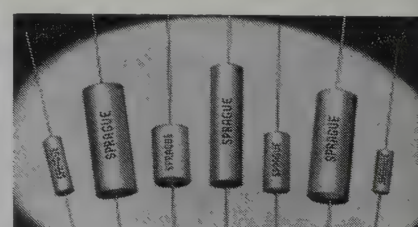
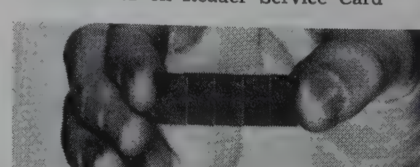


Silicon Solar Cells

Diffused-junction silicon solar cells announced by Texas Instruments Incorporated are now commercially available in a rectangular configuration, measuring one by two by 0.05 centimeters, both in single units and shingle arrays. The units possess a high degree of mechanical ruggedness and when formed into shingle arrays are guaranteed to resist a minimum static load of 16 ounces per contact without rupture.

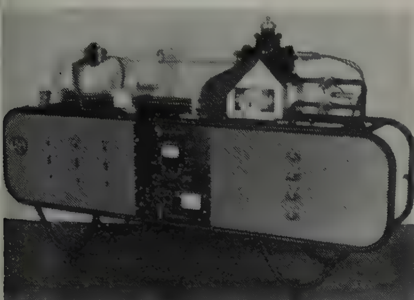
Circle 82 on Reader Service Card



Zone Refiner

Model Z-82 zone melting apparatus, introduced by Materials Research Corporation, is controlled by a completely new automatic program drive invented in the MRC laboratories. It makes it possible to perform zone refining, zone leveling or crystal pulling without constant attendance at the machine. The MRC Program Drive will turn off automatically after a preset number of passes; can be set for speeds from 0.10 to 18" per hour; has a quick return of 2" per second. Completely equipped with vacuum system.

Circle 92 on Reader Service Card



New Aluminas

J. T. Baker Chemical Company has developed four high-purity, finely divided alpha and gamma aluminas. Each type is controlled within a narrow range of particle size. The alpha aluminas vary from 0.02 to 0.4 microns and from 99.7% min. to 99.96% min. Al_2O_3. The gamma aluminas vary from 0.002 to 0.1 microns and from 99.7% min. to 99.96% min. Al_2O_3. In addition, J. T. Baker can produce a wide range of other micron sizes and purities depending upon customer requirements.

Circle 85 on Reader Service Card

Sonic Energy Cleaning Systems

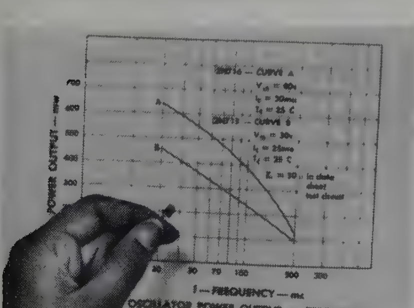
Newly revised Bendix Sonic Energy Cleaning systems have been announced. They use substantially smaller electronic generators and provide improved levels of sonic energy cleaning efficiency, while precluding noise and transducer cooling problems. The cleaners are accompanied by new coordinated units for rinsing, drying and filtering.

Circle 94 on Reader Service Card

VHF Silicon Mesa Transistors

Texas Instruments Incorporated two new silicon mesa transistors, 2N715 and 2N716, are capable of a guaranteed minimum power output of 500 milliwatts at 70 megacycles. These devices will deliver approximately 50 milliwatts at 200 megacycles. They have a guaranteed beta spread of 10 to 50 and a collector reverse voltage of 50 and 70 volts respectively. Collector reverse current at 25°C is 0.5 microamps maximum and 50 microamps maximum at 150°C. Temperature limits are at −65°C and 175°C.

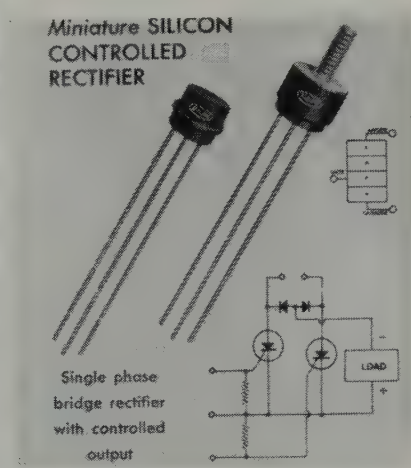
Circle 81 on Reader Service Card



Silicon Controlled Rectifiers

Precise power control of loads up to 300 watts with extremely low losses can be achieved reliably with a new line of miniature silicon controlled rectifiers in production at Solid State Products, Inc. At 100° C these units control up to one ampere (continuous) per cell with an input signal level of only 2 mA. Switching efficiency on the order of 98% is typical. At 2 amperes, the maximum drop is 2.5 volts. Minimum heat sink requirements with peak recurrent ratings to 30 amperes are afforded with low internal dissipation, operating over a temperature range of −65° C to +150° C.

Circle 100 on Reader Service Card



Gas-Tight Tube Furnace

The Pereny Equipment Company announced the addition to their "MT" series line, a new Gas-Tight Electric Tube Furnace for work requiring temperatures up to 2800 degrees F. It incorporates a 5" I.D. impervious mullite tube, with silicon-carbide heating elements spaced equidistant around it, and providing a 30" long hot zone with 3 separate zone controls for wide range, precision temperature control. Separate transformers, on each of 3 phases, are of the voltage regulating type with 36 (fine to coarse) taps.

Circle 97 on Reader Service Card

High Vacuum Pumping Station

A new 4" High Vacuum Pumping Station featuring pump down speed of 5 x 10^{-6} mmHg in 45 seconds, blanked port, and an ultimate pressure of less than 5 x 10^{-7} mmHg. is available from Veeco Vacuum Corporation. VS-400 is offered with a choice of forepumps and gauges. "Modular" in design, it permits additional equipment to be incorporated if and when required, i.e., base plate, base plate accessories, bell jar, power supplies, etc.

Circle 83 on Reader Service Card

High Power Zeners

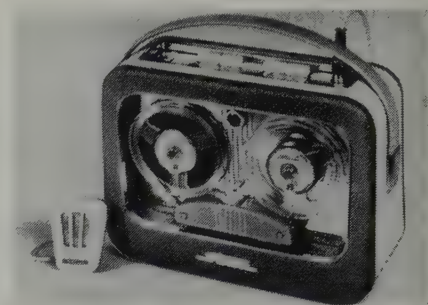
U. S. Semiconductor Products has developed a new high power Zener diode with standard tolerance of 5% in single units. Space and weight are saved, while power dissipation up to 35 watts is attained with proper heat sink. Zener voltages range from 8.2 to 100 volts at 500 to 50 ma. Zener or dynamic impedance is low, and breakdown is abrupt over the whole Zener voltage range. Matched coefficients of expansion, plus the diffused silicon junction, provide great resistance to vibration, mechanical and thermal shock. Performance is reliable under the most adverse environmental conditions.

Circle 90 on Reader Service Card

Portable Tape Recorder

Now available from Ercona Corp., is the Stuzzi Magnette, a fully transistorized, battery operated, completely portable broadcast quality tape recorder. Operates over 100 hours on 4 flashlight batteries; will record up to 2 hours on single 4" reel of tape. Weighs 8 pounds including batteries. The self-contained High-Flux Loud Speaker System provides superior tone quality for music, dictation, or conference recording even under the most adverse conditions, in any position. Completely vibration proof, incorporates a modern-design Amplifier system embodying 7 transistors and 2 diodes.

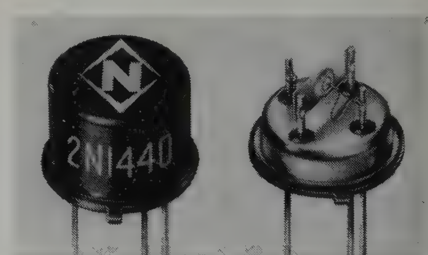
Circle 103 on Reader Service Card



Silicon Alloy Transistors

A new line of silicon alloy transistors for military and industrial electronic applications has been introduced by National Semiconductor Corporation. Type numbers 2N1440, 2N1441, and 2N1442 are specifically designed for small signal applications. Features include: device dissipation at elevated temperatures 100 mw at 125°C in free air; guaranteed maximum current gain and maximum collector cutoff current at 150°C.

Circle 101 on Reader Service Card



Lead Straightening & Taping Machine

Universal Instruments offers a fully automatic method of reel packing axial lead electronic components. Machine is adaptable to either lead taping or body taping, is readily adjustable for any body length or body diameter within the limits of the model design, is electrically operated and is equipped with variable speed control. It can be operated with or without an interliner for lead protection and for taping or straightening independently if desired. Will accommodate pick-up reels up to 16" in diameter and can be equipped with an automatic counting device. Machine can also be fed from other production line operations.

Circle 79 on Reader Service Card

Straightening Machine Attachment

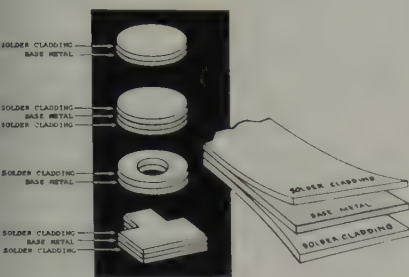
The Bulk Feed Attachment with Hopper for Universal Lead Straightening Machines will feed axial lead components from a bulk or boxed condition into an alining baffle type hopper and is supplied with variable speed control. It is a modular unit and can be used independent of other equipment. It will operate with any axial lead component that can be chute fed. Production rate is in the 8000 per hour bracket.

Circle 78 on Reader Service Card

older Clad Base Metal Stampings

Strips of base metals such as nickel, ovar, molybdenum steel and others are ow being clad on one or both sides with in-lead solders, silver, gold and related lloys through a bonding process devel-ped by Alloys Unlimited, Inc. Where urity is critical, as in semiconductor levices, new refining techniques enable Alloys Unlimited to supply clad metal tampings in the purity and dimensional olerances dictated by the application.

Circle 80 on Reader Service Card



99.999% Pure Aluminum Spheres

A process in the manufacture of tiny aluminum and alloy spheres has recently been announced by Semi-alloys, Inc. This new technique eliminates contamination inherent in punching and rolling operations by producing virtually perfect spheres with diameters from .001 to .125 inches, within critical tolerances of one ten thousandth of an inch.

Circle 98 on Reader Service Card

Military-Type Transistor

A new germanium switching transistor for use mainly in missiles and supersonic aircraft is being placed in production by the Bendix Aviation Corporation. The 2N1120 is particularly useful for *dc-dc* converters in high-performance aircraft and missiles. The unit has a maximum collector current rating of 10 amperes, and a maximum collector-emitter voltage rating of 70 volts. It will dissipate 45 watts at a mounting base temperature of 25 degrees C.

Circle 89 on Reader Service Card

Cadmium Electrode Transistors

Philco's Lansdale division announced an increased power dissipation capacity Micro Alloy Diffused-base Transistor (MADT). The new development involves the use of cadmium electrodes instead of indium electrodes. Cadmium's higher melting point (321°C) and thermal conductivity (4-to-1 better than indium) extends high reliability operation to increased dissipation levels. The new 2N501A and 2N502A transistors with cadmium electrodes can withstand overload power levels in excess of 200 milliwatts without catastrophic destruction.

Circle 93 on Reader Service Card

Microminiature Incandescent Lamp

An incandescent lamp, so small it can pass through the eye of a needle, is being produced by Sylvania Lighting Products. The Mite-T-Lite has immediate applications in transistorized circuits in missiles, computers and electronc systems. The body of the lamp is cylindrical with a nominal diameter of .040 inches. Nominal body length is 0.125 inches. The lamp leads are platinum in a diameter of 0.005 inches. The filament is 0.00025 inch tungsten wire of approximately 30 turns.

Circle 96 on Reader Service Card

Vacuum Oven

Specifically designed by Electric Hotpack for high temperature, low pressure drying and production line processing of transistors and other electronic parts. Unit is available in a choice of temperature ranges, from ambient to 200°C or 300°C. Vacuum is to 1 micron. Cabinet flanges allow easy attachment to dry box systems. Silicone door gasket insures positive vacuum seal; is reversible for double life. Double door design permits loading and unloading from opposite sides of the chamber for steady work flow; provides for removal of components or parts directly into a dry atmosphere.

Circle 87 on Reader Service Card

Silicon Computer Diodes

A new line of extremely low capacitance, very fast recovery silicon computer diodes has been announced by Pacific Semiconductors, Inc. with the introduction of the 1N925 through 1N928 series. The new subminiature diodes are characterized by maximum inverse capacitance of 4.0 $\mu\mu$ at zero voltage and typical inverse capacitance of 1.1 $\mu\mu$ at −10 volts. Maxaimum recovery time is 20K at 0.15 microseconds switching from 5mA to −10 volts.

Circle 95 on Reader Service Card

Transistorized Inverter

Varo Mfg. has produced a 500 VA static inverter for airborne applications. Operating from 28 VDC power, the Model 4312 produces both single and three phase power. The single phase output voltage is regulated to ±5% for input and load changes. A phase adapter converts a portion of the single phase output to three phase power for operation of gyros.

Circle 84 on Reader Service Card

Silicon Mesa Transistors

Rheem Semiconductor Corp., NPN, double diffused Silicon Mesa Transistors have exceptionally fast switching time, as low as 25 milli-microseconds. Saturation resistance is typically 5 ohms. These units are designed to meet the most rigid military specifications. They are available now in the JEDEC TO-5 package.

Circle 105 on Reader Service Card

PERSONNEL NOTES

Dr. Theodore S. Benedict has been appointed New Products Manager for the Electronic Chemicals Division of Merck & Co., Inc. He comes to Merck from Bell Laboratories, where he initially was engaged in basic research and later in technical and professional development work. In his new position Dr. Benedict will be responsible for technological liaison and market development of new semi-conductor compounds and of new applications for existing materials.

Tom Ciochetti has been appointed to the position of Sales Manager of Dallons Semiconductors, a division of Dallons Laboratories, Inc. The semiconductor division is located at 5066 Santa Monica Blvd., Los Angeles 29, California. He will be responsible for marketing activities in connection with Dallons' line of solid state devices. His background includes a BSEE from the University of Arizona and post graduate work in special instruments and rectifier cathodic protection.

Radio Receptor Company, subsidiary of General Instrument Corporation has announced three key appointments and promotions: Ralph Mendel has been named General Manager of the new Advanced Development Laboratory at Westbury, N.Y.; Arnold M. Wolf, has joined Radio Receptor as Vice President of its Engineering Products Division at Brooklyn, N.Y.; Seymour D. Gurian, has been named Vice President in charge of Military Marketing.

Harry E. Schauwecker is the newly elected President of Valor Instruments, Inc., Gardena, California. Previously, as Director of New Products Development, he was responsible for the development of the expanding line of transistorized instruments. Prior to joining Valor, Mr. Schauwecker was a transistor specialist at Gilfillan Brothers Inc. and Bell Telephone Laboratories. A lecturer in Engineering at U.C.L.A., he has taught an advanced course on Transistor Applications for several years.

Three Hughes Aircraft Company executives have been appointed to managerial positions. David A. Hill was named manager of the semiconductor division of Hughes Products Group. Lloyd H. Scott was appointed manager of Santa Barbara Research Center, a Hughes subsidiary. L. James Levisee was named director of materiel, general office. Hill formerly held the Santa Barbara Research managership; Scott had been director of engineering change management, and Levisee previously served as semiconductor division manager.

John P. McKenna has been appointed to the new post of Assistant to the President, LEL, Inc., Copiague, New York. Mr. McKenna was Contract Administrator at Airborne Instrument Laboratories, Division of Cutler-Hammer, Inc. for the past six years.

Sarkes Tarzian, Inc., Bloomington, In-
liana, has appointed Reincke, Meyer & 'inn, Chicago, as advertising agency for ts Semiconductor Division and its new Magnetic Tape Division. The appointment ecame effective on January 1, 1960.

Election of Richard A. Campbell as vice president in charge of operations of Pacific Semiconductors, Inc., was an- iounced recently by Dr. Harper Q. North, oresident. Mr. Campbell, who has served as manager of the Engineering Depart- nent since 1956 and has been associated with PSI since its inception in 1954, will be responsible for engineering, manufac- uring, reliability and sales department functions. He succeeds Warren B. Hayes, who has joined the PSI parent company, Thompson Ramo Wooldridge.

Austin Herbst has been appointed sen- or engineer in the solar methods depart- nent of Hoffman Electronics Corpora- ion's Semiconductor Division, El Monte, Calif., Dr. Morton B. Prince, division vice president-research and development announced recently. Mr. Herbst comes to Hoffman from Plas Kem Electronics, Bur- bank, Calif. He will be responsible for plastic encapsulation techniques for solar energy converters. He holds a Bachelor of Science degree in chemistry from Iowa State University.

A new organization structure, designed to meet current and future sales and op- erational requirements of the RCA Semi- conductor and Materials Division, has been announced including the following new appointments. Thomas R. Hays, Man- ager, Marketing Department. Norval H. Green, Manager, Entertainment Semicon- ductor Products Department. Kenneth M. McLaughlin, Manager, Computer Products and Materials Department. Barnes V. Dale, Manager, Micromodule Department.

Donald F. Christensen has been named Assistant Manager, Electrical Section, Product Engineering, according to T. A. Kauppi, Manager of the Dow Corning Product Engineering Laboratories. Mr. Christensen, a University of Michigan electrical engineer, joined Dow Corning in 1951. He has been actively engaged in the developments that have given silicone materials a leading place in insulation in the electrical and electronic industries.

Eugene L. Spencer has become admin- istration manager for Fairchild Semi- conductor Corp., Mountain View, Calif. Before joining Fairchild, he was man- ager of administrative planning for the Research Department of Lockheed Mis- sile and Space Division, Palo Alto. Mr. Spencer graduated from the University of California in 1949 with a B.A. degree in economics. In 1957 he received his M.B.A. degree in industrial management from the University of Southern Cali- fornia.

Fred Nelson Hurst of Brookside Farm, Lisbon Falls, Maine, has been named plant engineer for Raytheon Company's Semiconductor Division plant now under construction at Lewiston, Maine. Prior to joining Raytheon in August he had served as plant engineer with Stowe-Woodward Inc. A naval officer during World War II, Mr. Hurst is a member of the American Society of Tool Engineers.

New Literature

A data sheet on Bendix' new 2N297A military-type transistor, which has been designed to meet the specification MIL-T-19500/36A (SigC) is now available. 4-page sheet gives complete specifications with illustrations.

Circle 120 on Reader Service Card

Mucon Corporation announces a new bulletin describing the "Narrow-Caps" series of Subminiature Ceramic Capacitors especially designed for 1/10" modular spacing in printed circuitry, and other tight packages. Gives capacitance values in five stock sizes, Tolerance Temperature range, etc.

Circle 121 on Reader Service Card

Informative 4-page, two-color brochure on special line of Blue M Electric Company equipment, headed "Blue M Ultra-temp Ovens," has been announced. Attention is directed to units such as Recirculating Ovens, Miniature Batch Ovens, Mechanical Convection Ovens, and the entire Ultra-Temp Series. Bulletin includes complete construction details, voltages, prices and sizes of units available.

Circle 122 on Reader Service Card

Varo Mfg. Co., Inc., has compiled a brochure with their latest designs in static inverters. Plus an introduction into the theory of static inverters, this brochure gives the reader a concise look at single and three phase inverters. The type of voltage regulation and frequency control are also discussed.

Circle 123 on Reader Service Card

Engineering Bulletin 1004 deals with Ohmite Manufacturing Company's new, straight-cylindrical, wet-electrolytic, sintered tantalum slug capacitor. This unit is significantly smaller than Ohmite's longer established "hat-shaped" styles. Nevertheless, it offers the same range of capacitance and voltage.

Circle 124 on Reader Service Card

Electronic Research Associates, Inc. announces the availability of a new four page technical bulletin which provides full descriptive information on the company's newly introduced line of miniaturized, high current, solid state power packs. The technical bulletin provides background descriptive material on transistor regulators as well as detailed technical data on these high current solid state units.

Circle 125 on Reader Service Card

A new technical booklet on microwave diodes has been made available by Sylvania Electric Products Inc. The 12-page booklet contains complete electrical and mechanical data on all microwave diodes manufactured by Sylvania as well as a replacement guide to nearly 200 widely-used diode types.

Circle 127 on Reader Service Card

A new brochure describing a 2" High Vacuum Station achieving pressures of less than 5 x 10-6 mm Hg quickly is available from Veeco Vacuum Corporation. It describes in detail the performance, data and specifications of this unit which features an 85 liter per second, air cooled diffusion pump and the Veeco RG 3 ultra-stable ionization gauge and two station Thermocouple gauge control.

Circle 128 on Reader Service Card

A revised brochure, "General Plate Products," 3rd edition, 10 pp., describes the scope of Texas Instruments' Metals & Controls Div. line including solid and clad base metals, solid and clad precious metals, thermostat metals, electrical contacts, and the company's "industrial" metals: profile rolled strip, manganese age-hardening alloys, copper-cored glass sealing alloy wires, solid and clad reactor metals, clad metals for semiconductor applications and aluminum-iron alloys. The last three categories of industrial metals and copper-base Aliron are included for the first time in the 3rd edition.

Circle 129 on Reader Service Card

A four-page, two-color folder on predetermining counters has been issued by Veeder-Root Inc., describing and illustrating several of the major types of mechanical, electromagnetic, and photoelectric counters incorporating the predetermining feature. This class, or family of counters permits the operator to preselect a desired number of pieces, turns, strokes, lengths, or other units, simply by setting the desired number on the face of the instrument.

Circle 134 on Reader Service Card

"The Design and Usage of Miniature Pulse Transformers" a new comprehensive catalogue published by PCA Electronics, Inc., covers history of low-level pulse transformers, their chief differences compared to other transformer types, methods of measurement and theory of application. Also included is data on pulse transformer equivalent circuit, transformer polarization, methods of degaussing a core, manufacturing procedures, style and packaging.

Circle 130 on Reader Service Card

The SIE Transistorized Power Inverter, Model TPI-3, designed for power inversion in any airborne environment, is described and illustrated in a bulletin which outlines its specifications, features, and includes a simplified circuit diagram. Southwestern Industrial Electronics Co., a division of Dresser Industries, Inc.

Circle 131 on Reader Service Card

A new 17-page booklet which discusses applications of new and recently developed semiconductor diodes is available on request from Microwave Associates. "Applications of New and Recently Developed Diodes" was written by Dr. Arthur Uhlir, Jr. It covers such topics as varactor characteristics and measurements, varactor computers, silicon mesa computer diodes, the Esaki tunnel diode and thermoelectric devices. The booklet was prepared as a supplement to Microwave Associates' brochure "VARACTORS," with particular emphasis on the use of varactors as modulators and harmonic generators.

Circle 126 on Reader Service Card

Index to Advertisers

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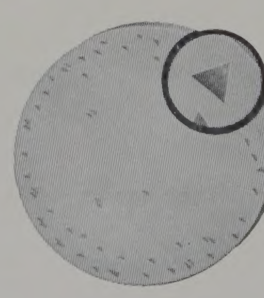

Dislocation density, Knapic silicon monocrystals grown by a modified Czochralski technique: Crystal diameter to ⅜"—None; ⅜" to ¾"—less than 10 per sq. cm.; ¾" to 1¼"—less than 100 per sq. cm.; 1½" to 2" less than 1000 per sq. cm.

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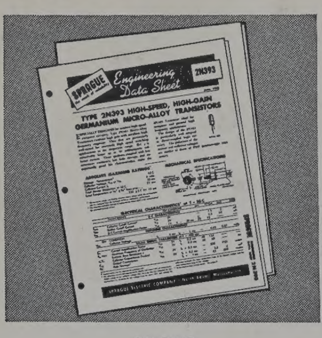

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2N393

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